

GEOLOGICAL SURVEY OF MICHIGAN
ALFRED C. LANE, STATE GEOLOGIST

**GEOLOGICAL SURVEY OF MICHIGAN
LOWER PENINSULA
1900-1903**

VOL. VIII

PART II

COAL OF MICHIGAN

ITS MODE OF OCCURRENCE AND QUALITY

BY
ALFRED C. LANE

ACCOMPANIED BY NINE PLATES AND NINE FIGURES
INCLUDING ONE COLORED MAP

PUBLISHED BY AUTHORITY OF THE LAWS OF
MICHIGAN
UNDER THE DIRECTION OF
THE BOARD OF GEOLOGICAL SURVEY

LANSING
ROBERT SMITH PRINTING CO., STATE PRINTERS AND BINDERS
1902

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OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICHIGAN, July 17, 1901.

To the Honorable, the Board of Geological Survey of Michigan:

HON. A. T. BLISS.
HON. LINCOLN AVERY.
HON. DELOS FALL, *Secretary*.

GENTLEMEN—Herewith I transmit as Part II of Vol. VIII, a report by myself, containing the results of my examination of the coals of the State in a general way.

Although it does not pretend to be exhaustive in its description of the wealth of the State in this particular material it seems to me that it may help give some idea as to the known variations in quality, which is better on the whole than has been reported, may help those who desire to test the quality to do so to best advantage, may give some idea of what has been done, and yet remains to be done in testing, and may save some useless exploration. If I have given especial attention to the probable depth to which it is worth while to test and have depicted the hindrances quite fully it must be remembered that forewarned is forearmed. I have not attempted to trespass on the field of the Commissioner of Mineral Statistics, and the Coal Mine Inspector, Mr. Wm. Atwood, whose valuable reports are made at frequent intervals to the Labor Commissioner, except so far as it has been necessary to use the facts gathered by them in studying problems proper to economic geology.

The records herein given of test borings are reported to us, and I do not guarantee their accuracy. I think that so far as they throw light upon the area and thickness of the coal series as a whole they may be trusted.

Not so much reliance can be placed upon the indications for individual beds, but in any case these can vary much in a few yards.

With great respect I am your obedient servant,
ALFRED C. LANE,
State Geologist

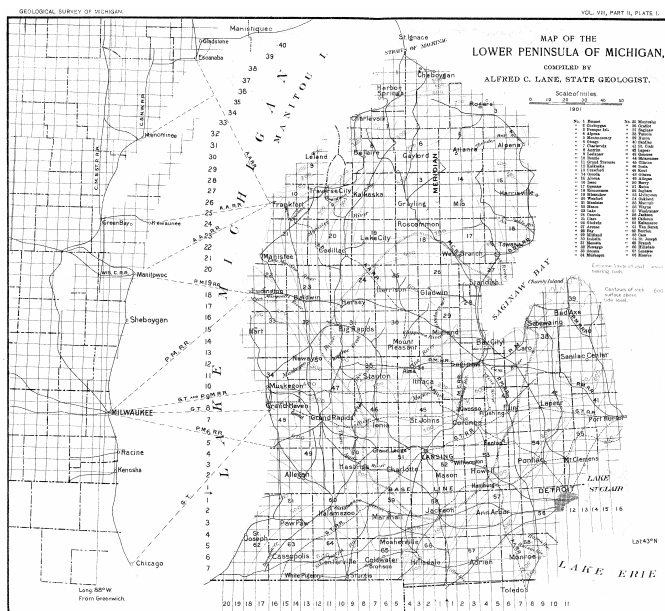


Plate I. Geological Map of Coal Basin.

CHAPTER I. INTRODUCTION.

§ 1. Object and history of this report.

This report was prepared in the fall of 1898, at a time of rapid development in the Michigan coal basin, to anticipate and help that development. Its primary object was to give the land owner of Lower Michigan that amount of geological information which would enable him to form an intelligent estimate of the value of his land for coal mining purposes, and to plan intelligently for the economical development thereof. As it could not be published by the Board when prepared, the Board authorized the Michigan Miner to print it serially. The publisher thereof furnished 500 reprints. As these are all gone, and the Board has now ampler means for publication, it is proper for the State to reprint the same in uniform style with the other publications of the Board, for the previous publication cannot be regarded as official.

At the same time the opportunity to bring the report up-to-date has been used, and the discussion of the heating values of our coal has been made far more full, and new formulæ, derived from our analyses, computed for estimating the relative heating value from the proximate as well as the ultimate analysis, and from the reducing power of the coal.

The discussion of the correlation of the coal seams is also extended a good deal and a brief summary of explorations so far as made public is offered.

It was prepared in accordance with that paragraph of the act establishing the Geological Survey that provides for "condensed statements, * * * as often as possible, * * * of important and interesting facts for general circulation,"

and is deemed advisable and timely, in view of the recently quickened interest in the coal deposits of the Saginaw Valley, and the rapidly increasing production of coal.*

The hour came when the "inexhaustible supplies of pine" of the Saginaw Valley were practically exhausted. It was no longer necessary to burn slabs to get rid of them. The price of coal imported from Ohio and Pennsylvania was no longer subjected to this healthy competition. This meant that for the continuance of the salt manufacture, and growth and continuance of other industries, a cheap fuel must be found to take the place of slabs. The economic hour struck when the supplies of coal more or less known for fifty years, and outlined by the geologist many years ago, were to be utilized. This development began in 1895.

*Revised Laws (1523), Title V, Part V, Chapter 55, Sec. 6.

§ 2. Comparative development in other States.

But, as we shall see, the abundance of cheap wood combined with other and peculiar difficulties to retard the development of the Michigan coal basin in comparison with that of other States. In the intervening years neighboring States have made tenfold the output that we have. Now that we do need to develop our resources, we may have the benefit of their experience if we will, and we shall be foolish if we do not avail ourselves of it. For there are certain rules as to the way coal occurs that have proven so widely true, that they may be expected generally to hold true in the future, though, as for all rules, we may expect some exceptions. In thus drawing on the experience of other regions I shall use especially States lying near by in the Mississippi Valley, and recently studied, examined and reported upon, to wit, Ohio, Missouri, Iowa and Indiana. I shall lay down a rule which I take to be applicable to the occurrence of coal in Michigan, shall state briefly some of the facts that indicate that the rule applies in this State, and then cite the authorities that declare the rule to hold true elsewhere.*

*For Iowa, Iowa Geological Survey, Vol. II, by Chas. Rollin Keyes, Des Moines, 1894, hereafter cited as Keyes, Iowa, 1894; also Vol. VII, Annual Report for 1896, with accompanying papers, Des Moines, 1897, especially pp. 263-413, "Geology of Polk County," by H. F. Bain, cited as Bain, Iowa, 1897; also an article by H. F. Bain in the Journal of Geology, published by the University of Chicago, Vol. III, p. 646.

For Ohio, of the Reports of the Geological Survey, Columbus, Ohio, especially, Vol. V, Economic Geology, pp. 1-300 and 773-1089, cited as Orton, Ohio, 1884; also Vol. VI, Economic Geology, Columbus, 1888, cited as Orton, Ohio, 1888; also Vol. VII, Economic Geology, Norwalk, 1893, pp. 255-290, cited as Orton, Ohio, 1893.

For Missouri, Preliminary Report on the coal deposits of Missouri, by A. Winslow, Geological Survey of Missouri, Jefferson City, 1891, cited as Winslow, Mo., 1891. In this work on p. 31 is a useful list of further references, and Mr. Winslow published much the same general account in the Bulletin of the Geological Society of America, Vol. III, 1892; pp. 109-121, cited as Winslow, 1892.

For Indiana, the 23d Annual Report of the State Geologist, 1898, is a very detailed work.

Both Keyes and Winslow derived much from the older reports of the Pennsylvania Second Geological Survey, under J. P. Lesley, which has made very voluminous publications, and Pennsylvania may be taken as the type State of the Union for the Carboniferous series.

Of particular interest and instruction for us is that by J. J. Stevenson, KKK, Report of Progress in the Fayette and Westmoreland District of the bituminous coal fields of Western Pennsylvania, Part II, the Ligonier Valley, especially Chapter II, p. 283. This State also publishes the reports containing Lesquereux's most thorough work on the coal plants. The Pennsylvania reports are cited by capital letters, KKK, P, etc. On the same region, but extending farther south, is Bulletin No. 65 of the U. S. Geological Survey (Washington, 1890), by I. C. White, price 20 cents.

In the Bulletin of the Geological Society of America, Vol. IX, pp. 35-58, is an interesting paper by W. S. Gresley on "Clay veins vertically intersecting coal measures." On the statistics and business of coal, W. J. Nicoll's 'Story of American Coal,' Philadelphia, 1897, and the annual volumes of Mineral Industry, issued by the Engineering and Mining Journal, and the parts devoted to statistics of the Annual Reports of the U. S. Geological Survey may be consulted. On methods of coal analysis and determination see Chapter IV.

The reports of the various State Geological Surveys may be obtained upon application to them at the capital cities above mentioned, and separate reprints of papers published in the Bulletin of the Geological Society of America may be obtained from Prof. H. L. Fairchild, Secretary of the Society, Rochester, New York.

In the Twentieth Annual Report of the U. S. Geological Survey, 1898-99, Part II.—General Geology and Paleontology, there is a paper on the Stratigraphic succession of the Fossil Floras of the Pottsville Formation by David White, which is of interest.

§ 3. Authorities for Michigan.

The foot-note to the previous section has given some authorities outside the State. As regards the Michigan basin, we have the State reports, to wit: The reports of the State Geologist, Douglass Houghton, and his assistants, Bela Hubbard and C. C. Douglass, in 1839, 1840, 1841; the Biennial Report by State Geologist A. Winchell, in 1861; the report by Carl Rominger in 1876 (III of the present series); the report by Wright & Lane in 1895 (Vol. V of the same series); also the reports of the Commissioners of Mineral Statistics (those by C. D. Lawton, 1881-1888 particularly valuable).

Vol. VII, Part II (Huron county), contains a report on the area around Sebewaing. An early private paper and account of practical exploration near Lansing and along the Cedar River, chiefly, is by R. R. Lansing, "Exposition Concerning the Mineral Coal of Michigan," Detroit, 1854. In the Twelfth Annual Report of the Saginaw Board of Trade there are also some analyses of Michigan coal.

Concerning the recent developments we have two pamphlets issued by Mr. C. B. Schaefer. But I have had access to a large amount of unpublished matter. I may note especially an unpublished report by A. Winchell for the Detroit, Grand Rapids & Indiana R. R. on the prospects for coal along their line; a report by S. G. Higgins to the Saginaw Board of Trade on explorations south of that city; most of the original coal mine maps of the Jackson mines, which with other valuable and instructive data I owe to John Holcroft, Esq. Finally, I have also notes of personal visits among other points to Sebewaing, Corunna, Jackson, Rifle River, Owosso,

Grand Ledge, Williamston, the valley of the Thornapple, the results of systematic studies and surveys of Huron, Tuscola, Saginaw and Bay counties, and a very large amount of data concerning borings in various parts of the State which have been collected by the State Survey during the past few years, some of which were collected for a report on the water resources of Lower Michigan, published as Nos. 30 and 31 of the Water Supply and Irrigation papers of the U. S. Geological Survey. I am also deeply indebted to most of the mine managers and many drillers and others for information. But I *have not attempted to give all the facts* upon which the *general* rules summed up in this short report are based, but merely enough to illustrate and make clear their application. Most of the material must, however, be gathered from the daily press or unpublished sources. Of especial interest is the Saginaw Evening News of Saturday, July 23, 1898, "Board of Trade and Coal Development edition."

The statistics are given in the reports of the Labor Commissioner and the Commissioner of Mineral Statistics.

§ 4. Role of the man who wants an option.

The problem of estimating the mineral value of lands, is not easy, and one is quite as likely to over-estimate as to under-estimate it, as the human mind tends to exaggerate the unknown. The following tale has a familiar sound to me: "There was a fellow around here a while ago, who wanted an option on my land, and offered to pay a little cash for it, but I was in no pressing need of money, and I thought if there was anything to be made I might as well make it myself, so that I would wait and see what his explorations showed up. But that was the last I heard of him, and now I am sorry I did not take his money." Compare the fate of coal explorations around Saginaw as recorded in the Standish Independent, December 2, 1898.

There is a tale told of Dr. Rominger, which, whether true or not, illustrates the point, that in the days of the coal excitement on Rifle River along in the '70s he was approached by a homesteader, who wanted to know what his land was worth. "Well," said Dr. Rominger, "Your land is pretty sandy and not very good for farming; if you get \$10 an acre you had better take it."

"Ten dollars an acre! Why a man has offered me forty already!"

"Well, didn't you take it?"

"No."

"Well, then, there were two fools instead of one."

The role of the "man who wanted the option," whom for short we call the promoter, is often misunderstood even by himself. He is looked upon as one who has occult knowledge and wishes to take advantage of people's ignorance to beat them out of property, the value of which they do not recognize. This of course he may

sometimes do, just as any merchant may over-reach, but he has a legitimate and necessary business, and a useful part to play, even though the land owners knew all there was to be known, or though he told them all that he guessed or knew, as to the present or prospective value of their property. Incidentally we shall show what this legitimate business is.*

*See § 5. Promoter and land owner.

CHAPTER II. THE ORIGIN OF COAL.

§ 1. From vegetation.

To understand the occurrence of coal, and from our partial knowledge to predict how it will occur, requires some knowledge of its formation.

Without going into the details of controversies on minor points, we may say that such coal as we have in Michigan is universally believed to have been formed from the deposits of decaying vegetation. Wood and peat have been turned into coal, both by accident and by intentional experiments. That the coal of our coal measures was thus formed is shown, not only by the stems and leaves that are often preserved in connection, especially in the shales above and below, but by a woody texture which may often be brought out even in comparatively massive and uniform beds of coal, by sections of it cut so thin as to be translucent like veneers. For the nature of the vegetation one must consult more extensive works, like Lesquereux's Coal Flora, published by the Pennsylvania State Geological Survey (p. 635). All the specimens sent to Lesquereux by Rominger were the floating stems known as *Stigmaria (ficoides) verrucosa*. Fragments of forms known as *Calamites*, *Lepidodendron*, and *Sigillaria*, which are plants allied to the scour-rushes, club mosses and ground pine. Ferns are comparatively rare. Rominger who was a careful observer reported them only for Sixmile Creek, north of Owosso. Recent openings have, however, given us a better chance, and they are now known from Grand Ledge, the Standard Mine, Saginaw, and other points.*

Recent investigations have shown that the spores of such plants (like lycopodium powder or pollen) have helped to form quite a part of the coal, especially cannel coal. Seaweed and the herbs and plants of dry climates, like the cactus, do not furnish much coal-forming woody fibre.**

When we come to ask how much vegetable matter is required to produce coal, having due regard to the facts that coal is about twice as heavy as wood, and that wood contains much beside carbon, and that some part even of the carbon escapes in the process of conversion to coal, we find the shrinkage estimated at anywhere from 1 ÷ 10. to 1 ÷ 30.†

We can obtain some idea of the compression by noting how thin stems have become, which are turned to solid bright coal. The breadth will be somewhere between the diameter and half the circumference of the original stem. In a stem turned to solid coal which I recently noticed, the thickness was 1 ÷ 16 of an inch, while the breadth was 1¾ inches, indicating a compression of 1 ÷ 18 to 1 ÷ 28.

Thus to account for a bed of coal five feet thick we must account for the formation of a bed of vegetable matter over 60 feet thick, intermixed with considerably less than 10 per cent of sediment. This is not an extraordinary requirement, for peat bogs have been found 200 feet thick, with no bottom even then, and even in Michigan I have reports of a case where a fifteen-foot pole has failed to find the bottom of the soft semi-fluid muck under the comparatively firm top of such a bog.

*Page 44.

**Otto Kuntze Geogenetische, Beitrage, Leipzig, 1895, 1895, p. 63.

†Englehardt, cited in Kuntze's Geogenetische Beitrage, p. 65, gives 3 ÷ 788; Keyes Iowa, 1892, p. 48, says that 4.5 feet of coal are equivalent to 30 ft. of wood, or 4 ft. coal= 60 ft. peat; Bain, Journal of Geology, Vol. III, p. 648, supposes a contraction of 1 ÷ 10 or 1 ÷ 16; Lesquereux (Pennsylvania Report P, p. 610) says that the annual layers of peat are about 1 inch thick near the surface, at 10 to 12 feet below are compressed and consolidated so as to be but 1 ÷ 10 of an inch, while in coal they are but 1 ÷ 20 of an inch thick, according to which it would take 240 years, or, if the coal plants grew twice as fast as peat, 120 years to form a foot of coal.

Sollas, Science N. S. Vol. XII, p. 308, following A. Geikie, estimates that peat bogs may have grown 6 feet per century, and coal 1 foot per century.

§ 2. Kuntze's classification of theories of coal formation.

Dr. Otto Kuntze in a recent work,‡ has given the most exhaustive and recent schedule of the ways in which the deposits of vegetable matter for the formation of coal may be formed. I translate his summary freely. His terminology is rather cumbersome. I do not recommend it.

I. Local or indigenous (Autochthonous) deposits: in which the deposition of the coal forming substance took place directly on the ground upon which the vegetation grew, without the intervention of water to spread it out in layers; with, interlaminated layers or rather streaks of sedimentary coal formed from leaves as an unimportant exception.

Under this head we have the following subdivisions:

Ia. Subtropical or tropical layers of lignite, i. e., brown coal, formed from forest clad swamps, without Sphagnum.

Ib. Recent peat formations, in cooler regions, formed by Sphagnum, i. e., floating swamp mosses.

Ic. Mixed formations,, from swamps only partly overgrown with trees and shrubs (like our tamarack swamps or the southern cypress swamps), which are

from time to time flooded with irregular deposits of sediment which produce lenticular laminæ that run out in all directions; this is because the growth of vegetation was continuous, and the repeated floods irregular and local, the detritus being generally drifted in different spots each time.

Id. Littoral swamps with irregular marine or brackish water admixtures, which may be explained by local alterations of the delta (formation of bars and tidal action) without catastrophic marine inundations.

Ie. Leaf coal, formed by the falling leaves and twigs of trees that grow on the banks of stagnant waters, which sink on the spot, are carbonized by the humic acids, and somewhat assorted and leveled off by the water. To this method of formation Kuntze attributes only coal streaks,—so subordinate components of the country rock or the coal (like the present formations in forest clad marshes) that they may merely smut, as it were, the principal mass of the coal or the country rock.

II. Derived or Transported (Allochthonous) deposits: those deposited irregularly in coarse fragments at a distance from the point where the vegetation grew. Only powdery detritus is deposited in laminæ if it floated away.

2a. Driftwood or other wood buried by accident (from trees or forests overturned or sunken with the soil) may form almost negligibly small components of the rocks or mere streaks of coal, but not layers of coal.

2b. Displaced coal beds, transported for example by ice action. The fragments of coal often found in the gravel and till, would be classed under this head. They are especially common in Michigan, in the sands and gravels, and especially when struck in wells often excite hopes which can only be disappointed. No coal without a good roof, and no coal that occurs in the surface clays, till, sand, or gravels, has any commercial value.

2c. Sedimentary peat: The very finest peat detritus is in exceptional cases somewhat washed away and may help to form,—

c'. Lake peat, with few or even no clay lamellæ, which are often visible only with a microscope.

c". "Papier torf," i. e., bituminous clay with infusorial earth charged with silicious diatoms.

c''' "Blaetter kohle," foliated coal, i. e., a marly clay with a little sedimentary peat mixed.

III. Marine (Pelagochthonous) deposits: Coarse waterlogged vegetable matter is deposited directly beneath the vegetation (which grows on the surface of the water) in sedimentary layers; a by-product is the powdery detritus which is often washed out of the coal-forming substance and deposited apart by itself as anthracite. (This theory of Kuntze as to the nature of anthracite is not generally accepted.)

3a. The normal Carboniferous coal beds (paralische) are, Kuntze thinks, composed of the remains of floating

forests, which grew out on the open sea. Such beds, he says, show no remains of trees that root in the mud, except in narrow districts that are near the margin, but are composed only of sedimentary laminated coal extending often over vast stretches, and in hundreds of beds which alternate with strata of inorganic material, each bed remaining nearly constant in thickness or running out in one direction. To this group he assigns the "paralische" coal fields of Naumann, which are most finely developed in North America and China, in which the many thin coal beds alternate with much more heavy strata of sediment and are not infrequently replaced with marine limestone. There are, however, also very thick as well as widespread pelagic coal fields. This is Kuntze's pet theory as to origin of coal, for which he argues at such length that reference must be made to the original article.

3b. Coal beds formed in the arms of the sea; more limited but in part very thick layers of laminated coal. Frequently on the side toward the deep ocean the coal layers wedge out into many separate layers, interdigitating with marine beds. Beside the remains of the floating marine forests are also abundant remains of trees that root in the mud. This group is most beautifully developed in France. Here belong in part the marginal ("limnische") coal basins of Naumann, who did not yet at that time divide the black coals into Tertiary coals without and Carboniferous coals with minute lamination. The Carboniferous coals are characterized as themselves marine formations by their frequent transition into marine limestone, and this also applies to the marine basin formations. The expression limnic, Kuntze would retain only for continental basins,

3c. Amorphous anthracite; consisting of the very finest detritus, with microscopic layers of clay, washed away and deposited by itself, from the Silurian to the Upper Carboniferous, in all regions, generally forming irregular layers. By anthracite in this sense is understood only the kinds most rich in carbon, which show no microscopic lamination, and "faser" or splint coal, stone coal, "staub" or small coal, and coking anthracite are excluded. Such amorphous and yet sedimentary anthracite, which, however, generally encloses "faser kohle," are, he thinks, only washed out of some other magma. Whether there are silurian anthracites which have been formed out of herbaceous vegetation only, Kuntze leaves an open question.

Really, however, to the cannel coals and certain laminæ in every bituminous coal this method of formation could better be assigned than to anthracite, which differs from bituminous coal in secondary alteration more than in anything else.

Of the various methods 1b and d and 3b and c seem most important in considering the origin of our Michigan coals.

‡Geogenetische Beitræge.

§ 3. Theories of Lesquereux and others.

Lesquereux was by far the ablest upholder of the theory that the coal was formed practically like the peat of bogs, and the Annual Report of the Pennsylvania Geological Survey in 1885* gives the latest account of his views, and at the same time of Kuntze's theory (3a), which he considers of all others the most able rival to his own. But one of the objections which he urges to Kuntze's theory, the conformability of the coal to the underlying beds if we may believe Winslow,† will not hold. The presence of underlying fire-clay 'beds' which is another argument which he uses against Kuntze's theory, is not universally true, and even when true would not, as it seems to me, exclude Kuntze's theory. One of the chief objections to Kuntze's theory in my mind is that so frequently heavy sandstones and other beds that appear to be formed along shore occur in the coal formation, that one can hardly think it formed far from shore. Moreover, there is no doubt that the tendency of recent investigation is to limit the extent of the continuous coal beds, in the Mississippi region at least, far more than either Kuntze or Lesquereux realized.** But as Lesquereux lays great stress upon the capacity of bogs to form floating superficial mats of vegetation, and speaks of the coal plants "Borne upon a solidly compact raft of creeping Stigmara," and since he and Kuntze both agree in regarding the Stigmara, contrary to a current view,‡ as horizontal stems, like those of the ground pine, but in water and with water leaves, serving to float (freely like the bladderwort, *Utricularia*), various kinds of vertical stems, their theories are really not so far apart. Both Kuntze and Lesquereux agree in what is a matter of common observation, that very little matter is carried away by rivers out of swamps, and with that the observation of every one will agree.

The wisest policy is to consider all possible methods of formation until the circumstances of each coal seam indicate the one or the other origin for it.

*Pages 94, 114; see also the final report 1895, pp. 1929-1930.

†Winslow, Mo., 1891, Chap. 1.

**See below, pp. [15] to [19], also the Indiana report.

‡Report P. p. 602.

§ 4. Practical bearing of different theories.

And yet as we find one method of formation more and more indicated we shall look to it more and more as the method of formation in cases when it is important for us to know in advance how a seam was formed. For these matters, interesting as they are as pure speculation, and fascinating as it may be to reconstruct the coal depositing forests in our fancy, have also a practical importance.

For instance, the 147-foot coal of St. Charles is much farther above the Marshall sandstone than the 80 to 120-foot coal at Sebewaing. If Kuntze's theory is applicable to the Sebewaing coal bed, we are likely to find it everywhere at nearly a uniform distance above the

Marshall sandstone. If, on the other hand, the Sebewaing coal was formed merely as a marginal bog, we need not expect to find it in strata which formed at the same time near the center of the basin. Or if it does extend out that far it may be above coal seams which were formed earlier at a time when the coal basin had not settled so far. A coal seam twenty feet above the base of the coal formation at the center of the basin would be earlier formed and geologically older than one an equal distance above the base of the formation at the margin. If Kuntze's theory applies we may expect to find the Sebewaing coal, which is about 142 feet above the Marshall sandstone, far below the St. Charles 147-foot coal, which must be over 500 feet above the Marshall.

Chemically, however, the Sebewaing and other coals of the margin are more like the upper seams of the center. The Sebewaing resembles the Lower Verne coal which can almost continuously be traced to the seam at 100 to 150* feet around St. Charles, while the deep seam at St. Charles, between 180 and 200 feet down is chemically like the Saginaw coal, and drilling indicates that it is nearly continuous. There are still lower coal horizons than this, so that if Kuntze's theory is applicable here, a correlation of the Sebewaing and Jackson seams with those of the Verne mine and the shallow seams of Bay City would be entirely inadmissible. In the one case we should expect to find the Sebewaing coal below the St. Charles upper coal; in the other we should not.

Keyes supposes the Iowa coal to have been formed in part, and mainly in marine swamps, but in part also in fresh water lakes, and in estuaries where driftwood might accumulate. Orton† ascribes a marine origin to many of the lower coals, and feels confident that the Sharon coal, to which, as we shall see, some of our coals are probably equivalent, was formed on the spot, in marginal swamps with the sea nearby, while the Freeport coals he takes to be fresh water coals.

David White assumes that the conditions of formation of the Pottsville formation in Pennsylvania were "a continuous broad base-level, coastal-plain shore and currents both strong and varying, so uniform and so rapid as compared with the geologic time required for the sedimentation of the terraces' that the similar associations of identical species occurring at different points along the coast are to be regarded as approximately contemporaneous."‡ "Brief periods of stability or even slight reactive uplifts, in conjunction with bar-forming currents may have assisted in producing lagoons, coastal swamps or other conditions suited either to the accumulation of vegetable matter or to the deposition of thin beds of argillaceous matter." Thus we see that geologists of adjacent States are not inclined to ascribe to all their coals exactly the same conditions of formation.

*See Pl. IX.

†Pages 812, 822.

§ 5. Probable formation of Michigan coal.

But on the whole the conception of the way our Michigan coal formed which it seems to me best satisfies the conditions of its occurrence is somewhat as follows: The center of Lower Michigan was occupied by an arm of the sea, or more likely an independent sea, like the Black Sea, opening to the southwest. The land had been higher (during later Kaskaskia time and while the Parma sandstone was depositing) just previous to the formation of the Coal Measures, and was settling slightly so that the river valleys were flooded like the shore of Western Michigan and Monroe county at the present day. The inlets, which are characteristic of a settling shore and represent the flooded lower parts of river valleys are often cut off by sand bars and dunes from the main sheet of water. Such are the lakes upon which Benton Harbor, Grand Haven, Muskegon, and Manistee are built. Out from the margin in the bays and inlets may have crept great floating bogs or mats of vegetation, tropical, closely matted, slowly decaying and weighed down by the ever-increasing growth above.

Occasionally it became overburdened and sank bodily,—an accident which happens nowadays to floating peat bogs overgrown with forest,—or the water logged part dropped bit by bit to the bottom. This green carpet over the water kept pushing farther and farther out and was somewhat like the ice forming around the edge of a lake in winter. Like that, too, an occasional storm would drive it back in winrows and perhaps swamp it. This floating forest shed abundant spores and pollen-like powder, which were blown and drifted all over the sea, helping to make a carbonaceous mud, which later became black shale, cannel coal, or bituminous limestone.

The rivers contributed their share toward filling up the sound, which may have been shallow, like Saginaw Bay, where the rushes wave from the water thousands of yards from the shore. There were probably minor oscillations between sea and shore, but on the whole for a while the land sank relatively and the sea overlapped unconformably on the land. Then the sea level remained fairly constant until the sea was largely filled up. Then the land rose and erosion began. But that we will consider later. I beg the reader now to hold this conception culled from the various theories in his mind, and as we pass to consider the actual facts as to the way in which Michigan coal occurs, to compare it with them, for it is by the facts that it and every other theory must be judged.

There are one or two of Kuntze's arguments, however, directly applicable to our Michigan basin, which we shall not have occasion to bring in later, and may glance at now.

In the first place, we may naturally account for the salty water which saturates the formation by supposing that the rocks were originally laid down in water at least brackish. In the same way the sulphates which are characteristic of the waters of the coal series may be derived from the sulphate of lime in the sea water, either

directly or through sulphides which were themselves derived from the decomposition of Ca SO_4 by organic matter, the S, or rather H_2S , set free picking up iron from bog iron ore.

If this is the origin of the sulphide of iron which is so constantly associated with the coal we can understand why there is practically no excess of sulphur, but just enough to combine with all the iron. That is what the chemist would expect if the iron and organic matter precipitated the sulphur from an excess of sulphated waters.

It is, however, conceivable that the salt and sulphates were derived by percolation from beds below, or by erosion of these beds, around the margin of the sea.

We may also note that our former State Geologist Dr. Rominger agrees with Kuntze in thinking that the *Stigmaria* were creeping stems (rhizomes). "Some of them," says Rominger,* "are found covered with leaves radiating in all directions—as if the apex of a branch had been immersed in the liquid clay paste without any disturbance of the expanded leaves. The leaves are long and band-like, flat at the outer end, sub-cylindrical, clavate and connected at the basal ends with the stems."

*Vol. III, Part I, p. 127. See also Scott's *Studies in Fossil Botany*, reviewed in *Science*, March 8, 1901. He considers them rhizophores.

CHAPTER III. OCCURRENCE OF COAL.

§ 1. Structure of coal.

If we examine a piece of our Michigan coal we see that it has a very distinct cleavage in one direction, though the cleavage is along warped or irregular surfaces, upon which frequently appear fragments of vegetation, apparently bits of rushes turned to coal. This cleavage runs parallel to the bedding and in the mine lies usually nearly horizontal. At right angles to this cleavage, standing nearly vertical in the mine, the coal is also divided by partings, known as joint planes or the cleat of the coal. The better developed set is generally called the face of the coal and the other the butt, and when they are both well marked and at right angles or nearly so, as is often the case, the coal is cut up by them into blocks or rough cubes, and is called "cubical coal," or "block coal." Where they are well developed it is easier to get the coal out in large masses, and in laying out a mine the endeavor is so to lay it out that the working faces will run parallel to the face of the coal. A charge of powder will then blow down the largest amount of coal from the under cut face instead of wedge-shaped pieces, as it would if the cleat of the coal ran diagonal to the working front. When the face parting is much the better developed the term cleat is sometimes applied to this alone, but sometimes the difference in the two partings is very slight, and their naming a matter of custom and

convenience, and sometimes the cleat is very poorly developed.

These partings cannot be put through anywhere in the coal, but occur at certain intervals. They are often smoother than the bedding planes, and not infrequently spangled with bright brassy coatings of sulphide of iron. This is a deleterious ingredient, but the spangles on these planes make a great deal more show than they do harm, and do not introduce half the amount of sulphur that is introduced in little obscure, hardly observable, apparently insignificant streaks parallel to the bedding. The sulphur is, as Mr. Hilton has shown (pp. 59 and 99), almost entirely in the shape of sulphide of iron, but the water of the region is strong of sulphate of lime, in which form the sulphur is by no means so injurious. I have seen little crystals of sulphate of lime (gypsum) on the faces of the coal. The analyses of Table A, CHAPTER VI.

THE DEVELOPMENT OF COAL seem to show that the sulphur naturally present as sulphates is less than one-third of one per cent.

Sometimes, too, the cleat faces are covered with thin white coatings of carbonate of lime, "spar" or fibrous gypsum.

If we look at these joint planes carefully we shall find on their surface the direction of cleavage or bedding marked by a series of lines where it cuts across thin laminæ. Some of these laminæ are bright and pitchy in lustre (German "glanz-kohl"), and are an essential constituent of cubical or block coals. Other laminæ are dull in lustre, soft black, have more the structure of charcoal, and have indeed the woody structure better preserved. These laminæ are known as fossil charcoal, mineral charcoal, fibrous coal (German "faserkohle;" in Great Britain "mother of coal"). Occasionally we may see dull, slightly brassy heavy streaks of sulphide of iron. Even when it is so smeared and sooted with intermixed coal as to appear black, such sulphide of iron may still be detected by the extra weight, and is sometimes known as black jack. But there is another black jack which is a sulphide of zinc, that I have seen in nodules in shales above the coal. Black jack is a term also occasionally applied to black slate, "jack" implying in a general way something of which to be rid. The iron sulphide is so much heavier than the coal that the coal may easily be washed free from a good deal of it.* A coal with much sulphur will, if left in a damp place, soon begin to split and become covered with delicate white needles which have a nasty inky taste, being made of vitriol (sulphate of iron, melanterite).

If our Michigan coal is put on top of a hot stove, it will yield after the steam is first driven off an aromatic smoke, long before it catches fire. This may be 'burnt as a gas. The matter thus driven off is the volatile combustible, a so called bituminous matter (it is not really chemically bitumen), which is present in all coking and gas coals. Michigan coal is to be classed as a bituminous cubical or block coal, inclining to be a gas coal and a coking coal, though these latter two qualities differ in different seams.

As all the coal of Michigan is probably not of the same quality it may be well to describe the different kinds of coal.

*See article in the Trans. Am. Soc. of Mech. Eng. Vol. XVIII, No. 708, Dec. 1896, on "The Washing of Bituminous coal by the Luhrig process," by J. V. Schaefer, Chicago, Ill. The Campbell washer is also much used.

§ 2. Varieties of coal.

We arrange the varieties of coal, so as to treat first those which have the most carbon in a fixed* condition, i. e., in such a state as to be burned off only at a red heat or higher, and not so combined as to be evaporated away in the aromatic smoke at gentler heats.

*See CHAPTER IV.

ANALYSES AND TESTS OF COAL., p. [27].

Graphite, the last stage of alteration of vegetable matter, is pure carbon except for the mineral matter. An impure graphite is found and mined in the Upper Peninsula of Michigan near L'Anse and is a frequent constituent of the Upper Huronian Slates.

Anthracite, hard, "stone coal," with but 3 to 10 per cent of volatile matter, as the analyses below given indicate. Almost all the anthracite used in the State comes from the Lehigh Valley in Pennsylvania, and in spite of newspaper reports, none has been nor is likely to be found in Michigan, at any rate in commercial quantities. Some of the so called graphite of L'Anse and the associated black slates is anthracitic in nature.

COMPARATIVE ANALYSES OF DIFFERENT KINDS OF COAL.

	Fixed carbon.	Volatile carbon.	Water.	Sulphur.	Ash.
Anthracite, Lehigh, av. of 20 analyses.	: 89.25	: 9.86	:	:	: 4.20
Anthracite, Schuylkill, av.	: 89.083	: 2.494	: 1.457	: 0.252	: 6.701
Semi-anthracite, Lykens Valley, Wisconsin, av. of 30 analyses.....	: 83.30	: 10.42	:	:	: 6.11
Semi-bituminous, Tioga Co.....	: 67.791	: 20.505	: 1.65	: 1.257	: 8.852
Bituminous, Massillon, Ohio.....	: 61.40	: 32.90	: 4.10	: 1.07	: 1.60
Bituminous, Massillon, Ohio.....	: 53.5	: 37.00	: 5.5	: 1.1	: 4.00
Bituminous, Connelville, Pa., coking.....	: 50.61	: 30.107	: 1.26	: 0.784	: 8.33
Bituminous, Butler Co., Pa.....	: 48.967	: 39.883	: 1.91	: 1.968	: 7.222
Bituminous gas coals, Clarksburg, W. Va.....	: 41.60	: 56.74	:	:	: 1.00
Peytons, cannel, W. Va.....	: 41.00	: 46.00	:	:	: 13.00
Clarksburg, cannel.....	: 45.43	: 49.21	:	:	: 5.36
Coshocton Co. Ohio, cannel.....	: 44.50	: 44.40	: 1.50	: 1.72	: 9.60
Lignite, Golden, Col.....	: 47.58	: 34.75	: 13.67	:	: 4.00

Semi-anthracite and *semi-bituminous* coal, has 10 per cent to 18 per cent volatile matter; is laminated, with bituminous layers and thin partings of cannel coal, or mineral charcoal; makes a dense coke especially good for blacksmith's work has not yet been found in Michigan and is not likely to be except in subordinate quantity. The Pocahontas coal stands on the line between semi-bituminous and bituminous. See also analyses in CHAPTER IV.

ANALYSES AND TESTS OF COAL..

Bituminous coal, with over 18 per cent volatile matter, of which about 4½ is hydrogen combined with carbon. This is the family of coal to which Michigan coals belong, and is subdivided into:

Steam coal (*block*, or cubical, when it breaks readily into rectangular pieces, *splint*, *furnace*, or *soft coal*). Open burning, with thin layers of cannel coal or mineral charcoal alternating with pitchy lustrous layers, melting and sometimes caking, but not compacting into coke. It may contain less bituminous matter than coking coal, but not always, and the line between these coals and coking coals is rather vague, and the connection with the composition of the coking property, not clearly made out. In fact, organic substances of exactly the same ultimate composition will, on being burnt, the one coke, and the other not, and a coal which will coke when first taken from the mine, may cease to do so when exposed to the air for a few days. Sometimes pulverization aids coking. Exposure to air deteriorates bituminous coal.*

*Orton, Ohio, 1893, p. 268; also Hale, R. S. and Williams, H. J. Am. Soc. of Mech. Engineers, Vol. XX (Dec. 1898), No. 798.

Coking (*cementing*, or *caking*) coal, is quite high in bituminous matter. The pitchy layers are broad, and separate thin dull laminae which are often broken. They are low in water, and may have from one-half per cent to 15 per cent ash. For the coke to be of most value it should be clear, bright, hard, open textured, with little sulphur. The best and simplest test of the coking capacity of a coal is to try it.†

†Sulphur seems rather to aid coking, but cannot be over 1% in coke for iron furnaces and anyway is not a desirable ingredient. Generally it can be largely driven off in coking. Moisture does not aid coking. Some coals will coke when ground fine,—disintegrated, which will not do so when heated in coarse lumps. There is an important article on by-product coke ovens in Mineral Industry for 1895.

Gas coal is usually a coking coal, but may be a cannel coal. It should be high in volatile matter and free from sulphur. All Michigan coal seems to run high in volatile matter.

Cannel coal is a very bituminous coal with a considerable amount of ash. One essential feature is the structure which is more compact than that of ordinary coal, so that it has not the alternation of light and dark laminae. Usually it is less pitchy and brilliant, though some varieties (jet) will take a high polish, but it is always uniform, and is a good gas coal. It is also a favorite coal for household use, as the large amount of ash, acting as a wick, makes it burn with less smoke. Hence its name cannel, i. e., candle. It "represents the carbonaceous mud from the surrounding swamps which furnished the cubical coal," and passes into black shale. In its make-up lycopod spores and pollen-like matter play a large part. The Michigan coals seem to lean generally toward cannel coal. It is often difficult to know where to draw the line, as I have elsewhere remarked* between cannel coal and black shale on the one hand, and common bituminous coal on the other.

**On the border line of coal," Michigan Miner, Vol. II, No. 1, Dec. 1899, p. 17.

Black shale while it does not show the layering of ordinary bituminous coal has a very well marked cleavage parallel to the bedding. The relatively weak

development of any structure parallel to the bedding so that the coal is quite likely to break with a shelly conchoidal fracture in any direction, is one of the main physical characters of cannel coal. If we draw the line by this physical test, however, we shall include under cannel coal, a good deal of what is often called bone coal, which has very inferior fuel value, yet is really a low grade cannel coal. Practically the line is sometimes drawn arbitrarily at 20 per cent of ash, and any coal which has over 20 per cent of ash is not counted as a cannel.

To one who is unfamiliar with coals, the following tests may be of help. If the substance shows bright and dull bands and in burning, that which is left after it ceases to burn with a yellow flame, appears black and melted, and full of bubbles (at any rate under a lens) it may safely be set down as bituminous coal. If the heat is continued the glow lasts quite a while when removed from the fire, and it slowly burns away, losing most of its weight, to a white or red ash.

If the substance does not show well marked bands, frequently breaks with a smooth, shelly fracture, and if on heating, after it ceases to burn with a luminous flame the ash is white or red or soon becomes so, and retains the original shape of the fragment, and appears to be a considerable proportion,—over one-fifth of the original, it may be classed as black shale, if it splits readily parallel to the bedding, or as bone cannel coal if it does not. If on the other hand there is no fissility parallel to the bedding and the amount of white or red ash left after complete combustion is less than one-fifth of the original substances we may safely call it cannel coal.

Above the coal seams there are frequently a few inches which vary in character from bone cannel to black shale, and contain shells shaped like a tiny flat spoon of *Lingula mytiloides*.

Some of the material tested by Mr. Willcox (CHAPTER V.

THE EROSION AND DISTURBANCE OF COAL., pp. 78-80) is of this bone cannel.

Beside the black shales associated with the coal there are others among Michigan rocks which have led to much waste of money. Most conspicuous are the Devonian black shales, which run across in a band from the south side of Thunder Bay to Charlevoix and Antrim counties, and from Port Huron and Detroit southwest. An analysis of one such shale, from south of Alpena, showing its fuel value is given in Part I of this volume on p. 47.

It will be noticed that the analyses of Michigan coals given in CHAPTER IV.

ANALYSES AND TESTS OF COAL., most resemble among the analyses of other coals given for comparison, those of cannel and gas coals. This is especially true of the Verne coal seams. The very large amount of volatile matter which seems to be present makes an excellent gas coal, whenever a coal low in

sulphur can be obtained. The Saginaw coal is very low in sulphur, and tests given below indicate that it would give a good fuel gas.

Comparing the three deleterious constituents, ash, sulphides, and volatile matter, and arranging the uses according as they can stand or prefer more or less of them, we get the following table:

Volatile matter	: Ash	: Sulphur
can stand much of the ingredient		
: gas man'f	: gas man'f	: steam making
: coking	: domestic	: domestic
: steam making	: coking	: coking
: smith work	: smith work	: smith work
: domestic	: steam making	: gas man'f
Presence of the ingredient disadvantageous.		

Both the Sebewaing, the Wenona, the Jackson coal and in fact the Verne seams generally are coking coals, and when they are used as steam coal tend to run together, and mass on the grate unless properly handled with a special grate. In spite of the coking properties, the percentage of sulphur in the Verne coals is often too high to make good gas coal or coke without wasting. Water is also high. The sulphur combined with iron is more harmful in other ways than in heat production. Coals with iron usually give red ash. The Lykens anthracite coals are known as red ash coals and our Michigan coals are geological equivalents. A white ash coal is probably pretty free from sulphur as well as iron. If in the analyses of the Sebewaing coal, we assume that there was originally enough iron which has all gone into the ash as Fe₂ O₃, to make Fe S₂ of all the S, almost all of the ash must have been iron oxide and all the coal combustible except the water. The amount of heat given out by the Sebewaing coal is very considerable.*

*CHAPTER IV.
ANALYSES AND TESTS OF COAL., Analysis A9.

Lignite or *brown coal* is a form intermediate between peat and coal, which is not found practically important in Michigan, though an important fuel in the far west (see analysis of Golden coal), and if present would not be likely to be used in the presence of abundance of coal. The same remark applies more or less to—

Peat, which is the consolidated mass of vegetable matter, largely moss, which is found in and beneath peat bogs, and is often called muck, but contains more mossy and woody substance than the proper muck, being composed largely of sphagnum mosses.

The cranberry marshes and tamarack swamps are the localities where peat most abounds, and up to the present peat has been known in Michigan chiefly as the base of the famous celery and peppermint soils, though for such culture, there must be about one-third of minerals constituents and sand; i. e., ash. In other words they are truly muck. Moreover they must not be acid. Peat frequently is. Analyses of these soils are given in Bull. 99 (July, 1893), of the Agricultural College. Peat has also been used, more especially the mosses which produce peat, as a packing for nursery stock.† Winchell‡ also has given quite an account of the various uses of peat.

Peat is the characteristic fuel of Ireland and has been used in other places for a long time, but its exploitation as a fuel has made great advances of late owing to the introduction of improved machinery in cutting and preparing it.§ It is also said to be available for the production of fuel gas, ammonia sulphate, acetate of lime, methyl alcohol, tar and coke briquettes,—that is to say, the same products which are given by the distillation of wood and soft coal.

†Sherzer, Monroe County, Vol. VII, Part I.

‡1860, pp. 192, 193.

§See "Die Torf Industrie * * *"by Dr. Theodor Roller, published in Vienna. Hertleben, publisher, 1898.

There are a number of peat factories in Ontario, where there is no local supply of coal. It is said to sell for about \$3.75 per ton.

An unsuccessful attempt reported in Vol. I, Part I, p. 56, of these reports was made to use it for fuel in pig iron manufacture. But beside the amount of water contained which runs from 10% up, it is liable to run rather high in phosphorus.

Peat bogs are very abundant in the northern part of the state* as well as in the southern and often occur in connection with, and sealing over marl deposits, and possibly they might be used in cement manufacture. Many descriptions will be found scattered through the reports of this survey from the time of Douglass Houghton on. Near Chelsea on the Michigan Central railroad are extensive deposits of peat, and the Chelsea Compresso Peat Co. has been organized to exploit them.†

The following analyses from Fritsche may be compared with Tables B and K of CHAPTER IV.

ANALYSES AND TESTS OF COAL.. Peat in the bog, it must be remembered, is very wet and entirely unfit for fuel, and the amount of drying and consequent loss of water in the merchantable product varies greatly. A peat with 16% water and 8.5 ash will yield about 3,800 to 3,900 calories. See p. 118.

	H ₂ O	C.	H.	O.	N.	Ash.					
Harz, Germany.....	10-90%	50.86	5.80	42.57	0.77	0.57					
Holland.....		59.27	5.41	35.32	1.79	2.04					
ASH ANALYSIS.											
	K ₂ O	NaO	CaO	MgO	Al ₂ O ₃	FE ₂ O ₃	P ₂ O ₅	SO ₄	Cl	SiO ₂	Insoluble. (Sand.)
Harz.....	1.33	1.45	23.78	15.59	10.69	6.76	5.50	10.06	1.82	4.40	17.32
Holland.....	1.2	1.1	11.7	4.5	2.9	5.3	—	9.7	1.5	9.8	51.5

A few other terms often used by miners may also be defined.

*E. g., 8 feet thick right in Redjacket; See Calumet News, July 31, 1901.

†Detroit Journal, August 24, 1901.

Bone coal is a name applied to cannel high in ash, and to coal and slate inseparably mixed, and may show horizontal stratification. It represents a transition toward black shale, but need not be so compact, nor so uniform, nor necessarily so bituminous as cannel coal. A layer of

bone coal overlies the main coal at Sebewaing, and is separated from it by a streak of sulphides.

Charcoal is a term improperly applied sometimes to slate and coal mixed, with stratification more or less twisted, and with FeS_2 more or less intermixed, as well as to the duller less altered streaks in the coal, which we have already described.

§ 3. Slate partings.

The mention of slate in coal naturally leads to the subject of "slate" (or more properly shale) "partings," which may be no wider than a knife blade, but often are an inch or two thick, and though very thin may be persistent for a good way. They may even thicken so that what was mined as one bed of coal becomes several distinct beds. In the Glen Mary mine of East Tennessee, the superintendent informs me that the two seams of coal, separated only by a thin parting on one side of the basin, are three feet apart at the bottom, and on the other side have been followed continuously until they are at least forty feet apart. Similar phenomena occur in Michigan, especially in connection with the upper coals. This implies that the distance between different coal beds is not always the same, but may vary greatly. To such an extent is this true that Stevenson hazards the suggestion that possibly all the lower coal beds of Pennsylvania may be split off from the one great Mammoth seam. This splitting of coal beds cannot be absolutely proved by comparison of disconnected records, but only by following them continuously in mines or in sections made by streams, but we have such proof in Michigan in the Wenona, and Michigan mines of Bay City and many of the records suggest the possibility of such occurrences.

§ 4. Character of the roof.

The usual beds above the coal are everywhere reported to be black shales, and in reports of explorations, unless great and conscientious care is taken, more or less of this black shale is likely to be counted with the coal. Sometimes this black shale is almost a cannel coal, and this is the case with the fossiliferous bed, the Lingula shale, which overlies the coal in the Bay City and Verne mines. Other varieties of the shale roof will be found described in Part I of this volume on clays and shales. The black shale is an impervious roof, which is important when water is so abundant as it is in Michigan, but is likely to be weak, especially when the rock surface is not far above, and requires a good deal of propping of one kind or another.

At times we find coal directly beneath clay, sand or gravel, or other unconsolidated deposits, when it is practically unworkable. Black shale with a firm sandy shale or sandstone above makes an excellent roof unless it peels off and comes down as "draw slate." A sandstone roof directly above will be found a very wet roof. I know of no mine that claims to be working under a limestone roof, though the roof at the Michigan and Amelith shaft of the Pittsburg is a black bituminous

limestone full of shells (Productus, etc., see p. 42), which are like those found at Verne, and the roof of Tod Kincaid's coal mine near Corunna is said to yield 50 per cent of CaCO_3 . Probably limestone beds are pretty widely associated with the Verne coals.

It is probable that our coals belong in the Pottsville formation, corresponding to the Sharon, Quakertown, and Mercer coals of Ohio, and the limestone roofs are especially found over the Upper Mercer coal and the coals of the Lower Coal Measures. The weakness of the roof has been the ruin of many mines. Next to the water it is the most serious source of expense.*

The deeper coal seams nearer the center of the basin may be expected to be better as to roof.

As we have said, in Michigan the shale above the coal is almost invariably black. Sometimes blue shales are reported, and it is generally blue a few feet above. In fact so characteristically do our Michigan coals appear to be associated with shales, and so rare are the cases when anything but shale, slate or fire-clay, are reported above or below, that they may be presumed to be generally mere local phenomena.† In the overlying shales are very often nodules and bands of carbonates of iron, lime, etc., kidney ores as they are often called from their shape. A very interesting occurrence is that of the nodules which also contain sulphide of zinc with sulphide of iron, which I found in the shales over the coal in the Owosso Coal Co. mines northeast of Corunna; also at Grand Ledge, at the Standard mine Saginaw, at Sebewaing and at Flushing, and also I am told in the shaft on Sec. 7, of James Township, T. 11 N., R. 4 E. I have also found kaolinite.

As we shall later see, there are a number of reasons for considering one of the coal seams mainly worked in Michigan, as nearly equivalent to the Sharon or Massillon coal of Ohio, and it is interesting to note that White‡ speaks of the roof of the Sharon coal as commonly 40 to 50 feet of shale with nuggets of Fe CO_3 .

*Lawton, 1887, p. 133; 1885, p. 173, et passim.

†The difference between what the drillers call "slate" and shale appears to be that the former is harder and slakes less readily.

‡Bull. U. S. G. S., No. 65, 1890, p. 202.

§ 5. Character of the foot.

The bed underneath the coal (the foot) is usually reported as fire-clay or shale. Probably no stress can be laid on the difference, except that by fire-clay a white or light color is generally implied. Many drillers report all clayey beds under coal as fire-clay, where other drillers report always shale, and a record of a saline or other well for water might report the whole series as merely alternations of black, white and blue shale. Fire-clays are shales which will not melt in the fire and will make good fire-brick. They have a large proportion of fine SiO_2 (which is not surprising when we remember how largely plants like scour rushes occur in the coal), and have but little of fusing compounds, like alkalies, lime,

etc. As Ries's tests in Part I of this volume show, genuine fire-clay is absent or rare, but clays suitable for making semi-vitrified or paving brick are common. For low grade fire-brick and paving brick, the demand for which is growing, such clays may often be mined to advantage in connection with thin seams of coal.

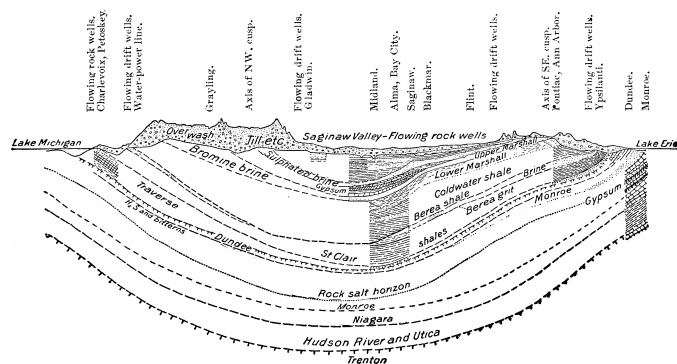


Figure 1. Cross section of the Lower Michigan Basin. Horizontal scale, 1 mile = .135 inch; vertical scale, 1,200 feet=.321 inch.

§ 6. The Michigan coal basin.

The outlines of the coal basin have been shown in Winchell's various maps of Michigan, in Volumes III and V of these reports, and in Nos. 30 and 31 of the U. S. Geological Survey water supply and irrigation paper. A rough map was also given in the preliminary addition of these papers, and in an article in the Engineering and Mining Journal for June 30, 1900, with contours also indicating in a rough way the system of rock channels.

Plate I of this report illustrates our present knowledge. In the Marshall sandstones themselves small streaks and pockets of coal and coaly impressions of vegetation are found also, but have never been found to possess more commercial importance than the driftwood along the beach.

Figure 1 and description taken from my paper on the water supply of Michigan* gives an idea of a cross-section of the strata of the basin from southeast to northwest, only those of the innermost basin above the sulphated brines being the coal measures.

The Devonian black shales are those which lead most often to false reports of coal.

The area enclosed on the map, Plate I, includes also the basal or Parma sandstone, which is, however, not everywhere present. The boundaries of the basin are fairly well known east of the Meridian line, but the northwestern portion is more uncertain. All that we have to go by are certain general considerations as to the thickness and dip of other beds, the relations of the drift and the present topography to the underlying topography, the coal in the drift and the direction in which it came, etc., which are almost too complex to go into here,† and a few scattered drill holes.

Some distance beneath the coal series proper there is a sandstone known as the Napoleon or Upper Marshall,

which can be followed in outcrops or in drilled wells from the sandstone bluffs of Huron county into Sanilac and thence southwest past Island Lake and Napoleon into Hillsdale county, and thence northwest, past Battle Creek to Holland, and thence, in wells, on to Grand Haven, Muskegon and Ludington. It is also recognizable in wells around Tawas and northwest, and since it is full of water, which over much of the Saginaw valley will rise to the surface, it has been tapped by a great many wells, for fresh water near the margin, for salt and bromine toward the center. We can thus follow it pretty continuously over two-thirds of the basin.

The greatest depth below surface to which it has been followed is at Midland (1200-1300 feet) and St. Louis and Big Rapids (1300 feet). The outcrop, or what would be the outcrop, were the surface deposits stripped off, is generally under higher land than the surface of the coal basin, which it thus surrounds as a rim. This bed is practically equivalent to the Upper Logan of Ohio. *Beneath it and outside it no coal in commercial quantity has been or is likely to be found.*

*Water Supply and Irrigation paper of the U. S. Geological Survey, No. 30, Fig. 10.

†The cusp dividing the Saginaw and Erie ice lobes we know followed on the southeast the ridge of Marshall sandstone underlying the coal basin. So on the northwest it is a fair presumption that the dividing cusp between the Saginaw ice lobe and that of Lake Michigan, which retired north and northwest from Grand Rapids, followed the heavy sandstones underlying the coal basin,—either the Marshall or the Parma.

Again coal in the till or terminal moraine deposits must have been derived from a source nearer the center of the ice sheet along the direction of lines of motion of the ice. Coal in alluvial deposits must have come down hill.

The coal series appears to have been well represented in the Big Rapids Red Cross well, and coal is found in the drift as far north as Roscommon county. Now coal in the till has always been moved to southwest of the rock outcrop.

This point needs to be emphasized, for in the Detroit papers of March, 1898, I saw a write-up of two columns concerning coal in Wayne county, and not many years ago considerable time and money was wasted in putting down a shaft for coal in Antrim county. More recently some of the pushing business men of Alpena underwent the same experience, and even now, I hear of coal explorations in Sanilac county, at New Baltimore, etc., which are sure to be futile. To explorations for coal outside the limits shown upon the map I can give no encouragement.

It was at one time supposed that the coal fields of Michigan, Ohio and adjacent states were originally continuous and were afterward folded very gently, and the coal on the arches eroded away, while that in the basins being less exposed to such action was preserved. Such was often the case in Pennsylvania. But it is now understood that these fields were never continuous.*

*Keyes, Iowa, 1894, p. 173.

This is of practical importance, for if they had been we might expect to find occasionally outliers outside the main basin. The evidence in the case of Michigan is somewhat as follows: We find overlying the Marshall sandstone, in the deep wells of the Saginaw Valley, a series of shales with beds of gypsum which extend from Alabaster and Huron county to Grand Rapids, where they outcrop.

Now the gypsum (sulphate of lime) is a salt present in seawater, and one of the first to crystallize out, when an arm of the ocean is cut off from the main body and exposed to a climate such that evaporation goes on faster than water is supplied. This gypsum we do not find in Ohio, or other states. Hence it is natural to suppose that the gypsum was laid down in an enclosed basin cut off from the main ocean to the south. As a matter of fact we do find a group of strata, the Logan series,[†] which occur in Southern Ohio, but not in Northern Ohio where an unconformity indicating that that part of the State was then out of water takes their place. In the same way we find that in Michigan the gypsum series does not extend all over the top of the Napoleon sandstone where we might expect it, but that in some places the beds immediately above—the limestones of Grand Rapids and Bayport—lie directly on top of the Napoleon sandstone. Or as at Corunna, we find the Parma and Marshall sandstones indistinguishable. Again over in Ohio, we find a limestone which must from its fossils be equivalent to these limestones, the Maxville limestone, unconformably overlapping the beds below. Thus we have evidence of a neck of land projecting out from the land mass to the north (for Canada seems to have been out of water all this time), through Southeastern Michigan and Northern Ohio, having no deposits of Logan age, and hence a projection of land. We thus have a slight fold indicated, antedating* the formation of the coal measures of Ohio and Michigan and lying between them. The only way in which we can conceive the two coal basins to be connected therefore, is by submergence of this axis, and deposition over it. It is not of course necessary to suppose that the submergence extended to the full height of the fold, which was very likely folded as formed. Of complete submergence of this axis there is no sufficient evidence though this low projecting area seems to have been a little higher in the time of the Upper Marshall, i. e., Napoleon, than immediately thereafter. During the time of the Bayport limestone it sank a little, but the character of that limestone and the corals and sand bars and other shallow-water fossils found in it indicates that the depression was not enough to make the ridge entirely disappear.

[†]Orton, Ohio, 1888, p. 39.

*A reason for considering that the fold of the Marshall antedates the coal seams is found in the dips. While the top of the Marshall descends from 252 to 700 or 800 feet below the surface from Sebawaing to Bay City and Saginaw, the base of the coal measures descends from 104 or 120 to between 300 and 400 feet only; while it is doubtful if the coal seams descend appreciably.

Almost immediately above this limestone come the coal beds. Over in Ohio fragments of the Maxville are found in the conglomerates immediately above[†] (Herrick) showing that the movement of depression during which the limestone was formed must have been promptly changed into one of uplift which brought it within reach of erosion, so that its fragments could be worn away to be laid down in later formations. So around Jackson this limestone occurs on the tops of hills with the coal beds and coal measure series between and flanking them[‡] in a way that plainly indicates that the coal measures were deposited in troughs in the eroded limestone, so that the margin of the basin at the time of the deposit of these coal measures must have been in the region. It must not be supposed that the smooth outline of the coal basin given in Plate I is exact. It is merely the expression of our ignorance of details. It was probably very irregular and would have been more deeply indented if it had been taken at the top instead of the bottom of the Parma sandstone.

[†]Geol. Sur. Mich., Vol. VII, Part II (Huron County), p. 293.

[‡]Geol. Sur. Mich., Vol. III, Pt. I, pp. 116 and 129, and private communications of J. Holcroft and F. C. Ward of Jackson; see also Winchell, 1860, p. 117.

Inasmuch as coal cannot be predicted as certainly present anywhere in the coal basin, I have in drawing the limits of it tried to include all the land where it might even possibly be present.

As to the limited character of the coal basins in other states of the Mississippi Valley, says Orton of Ohio.* "The subsequent," to the time of the Berea grit, "history of the eastern half of the State depends upon the joint advance of these land masses, the western and northern borders of the gulf. Both seem to have extended themselves in the same manner by a slow and nearly uniform rise of the border," "the lowest coal seam was formed around the margin of the sea;" "the later coals never extended over the out- side margins of the earlier swamps." "At the time when the Sharon coal was forming, the area of the gulf in Ohio was not less than 10,000 square miles."

Says Keyes:[†] "It is a significant fact that the Palaeozoic coals of the world are all deposited in more or less limited basin shaped areas."

Winslow[‡] gives a map of Missouri, which shows quite well one-half of the basin as it exists there and§ describes the Coal Measures as flanking the Ozark uplift, which took place probably during the Carboniferous.

The following diagram, which is taken from Part II of Vol. VII modified from one issued by Keyes|| (Fig. 2), shows the general sequence of elevation and depression of the land and consequent advance of the shore to the south or retreat back to the north.

The land rose and the ocean retired south during the Kinderhook (Marshall), and Lower Michigan in part emerged from the water, and continued retiring more

slowly during the Augusta while the gypsum series was being deposited in Michigan in the cut off basins. The ocean advanced again during the time of the Saint Louis formation and finally at the time of the Bayport limestone forced open water communication as far as Huron county. Then it retired again during the Kaskaskia so that the Bayport limestone was eroded around the edge,—at Jackson and elsewhere.

*Ohio, 1884, p. 135; 1893, p. 264.

†Iowa, 1894, p. 91.

‡Mo., 1891, Plate 1.

§Mo., 1892, pp. 109-110.

||Iowa, Keyes, 1894, p. 114.

The upper Kaskaskia (Chester) and the very lowest coal measures were deposited only in the center of the coal basin, if indeed, that too was not land surface. Then during the time of the coal measures though there was some irregular readvance of the sea it never fairly regained what it had lost, for it filled up nearly as fast as the land sank.

	MISSOURI	IOWA	MICHIGAN
COAL MEASURES		SHORE	COAL MEASURES
KASKASKIA			PARMA SANDSTONE
ST. LOUIS			BAYPORT LIMESTONE
AUGUSTA	SEA		MICHIGAN SERIES
KINDERHOOK			UPPER MARSHALL
			LOWER MARSHALL

Figure 2. After Keyes (Iowa, Vol. II, p. 114) showing how the shore line advances to south and returned north during and before the deposition of the coal measures.

There is another point that shows that the Coal Measures of Michigan were deposited in an arm of the sea, extending into a basin which existed before their formation, and that they have not been folded into basin shape since. Beneath Sebewaing the Upper Marshall, Napoleon, is struck at about 250 feet* and the coal bed is from 85 to 125 feet in depth. At Midland the top of the Napoleon is at 1,200 feet depth, and consequently the coal horizon might be expected at some such depth as 1,050 feet if the strata were parallel. Instead of this at 1,050 feet we are in the gypsum beds of the underlying Michigan series, and we do not find any possible equivalent to the Sebewaing coal until we come to a black shale at 800 feet. The same state of affairs is generally true in the Alma, the Saginaw River wells,† etc. While the Napoleon is often over a thousand feet deep, proper coal measures are not found at over 800 feet depth.

Obviously, therefore, the coal formation is in a broad way more nearly horizontal than the Marshall sandstones and underlying beds, which must have been slightly folded before the coal was laid down. It follows that we cannot estimate the thickness of the coal series from their breadth and the dip of the Marshall. However, the earlier estimates, and in fact the estimates to this day current, concerning the thickness of our Michigan coal measures, being based mainly upon observations near the border, have much underrated them. Keyes for

instance speaks of them as not over 200 feet thick, half of which "is occupied by the basal sandstone." Instead of this there is not less than 600 feet of coal measures, excluding the basal Parma sandstone, at Midland, and probably somewhat more farther northwest.

*Vol. VII, Part II, p. 145.

†CHAPTER VII.

DEVELOPMENTS AND BORINGS..

§ 7. Minor undulations in the coal measures.

The coal lies in minor undulations, independent of the general curve of the whole formation and the basin which it forms. These are known to miners as "hills" or "rises," and "valleys" or "swamps." The coal is said to be pockety.

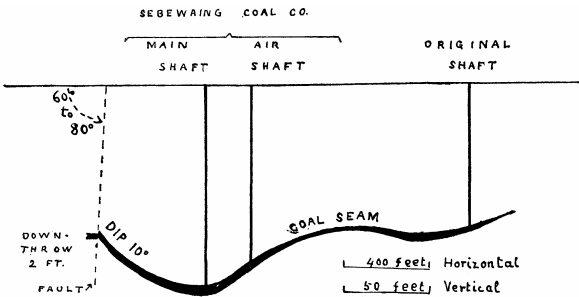


Figure 3. Section at Sebewaing Shaft.

Fig. 3, taken from Fig. 11 of Part II of Vol. VII, across the Sebewaing basin shows the structure. It appears again in the diagram of the Woodville shaft, Fig. 4.

I have been informed by the miners at Corunna that the rule is generally true there, and that as Rominger says, "The beds are found in the mine rising and sinking in undulations." At the Somers No. 1 shaft, St. Charles, again the coal is reported to be dipping and thickest to southward. Between Somers No. 2 shaft, and the St. Charles Coal Co.'s shaft are two rises. This is a very important feature in developing coal, for it is obvious that it will be much more economical and convenient to locate the shaft at the lowest points. Then in drifting out, all the water will run toward the shaft, the levels will be kept dry and the water can be lifted by one pump. Moreover the loaded cars will have a down grade, and the empty cars an up grade. A similar structure is described in all other States. Keyes* describes and shows in his figures very plainly the "shallow saucer shaped sheets of coal." Orton† mentions the same structure in the Sharon coal.

These minor undulations seem also to extend down into the Napoleon as we find in following the "lower salt rock" from brine well to brine well down the Saginaw River.

In the Pere Marquette No. 1 mine the coal rose so rapidly to the east that the roof became unsafe and leaky, and the mine is being abandoned and similar

undulations might be described from most of the new mines.

In the works of the New Hope Coal Mining Co. near Jackson the trough or valley is barely 150 yards wide, but is several hundred feet long.

*Iowa, 1894, pp. 176-179.

†Ohio, 1884, p. 156.

In these undulations the coal is generally thicker where lower, and "thins to the rise."

This is the general rule laid down in the text-books.

This is obvious in the workings of the Sebewaing Coal Company, Fig. 3, where the coal is 4½ to 5 feet thick near the shaft, and diminishes to two or three feet at the old first shaft, and beyond that runs out. At the former shaft it is 120 feet deep, and at the latter 86. It is true according to Mr. Holcroft generally in the Jackson region (Fig. 4, p. 33 and Fig. 5, p. 48), and also is known to be true around Corunna.

We find the same law reported for Iowa by Bain‡ and Keyes.§

"The coal may therefore be considered"—"as disposed in numerous basins of more or less area, thickened centrally, but gradually becoming attenuated toward the margins."

Similar facts are mentioned in Ohio by Orton. ||

‡Iowa, 1897, p. 299.

§Iowa, 1894, p. 176.

|| Ohio, 1884, p. 156.

In the lower and thicker parts these troughs of coal are likely to be capped by a smaller coal seam known as a rider.

As the word likely implies, this rule has not been made out with any certainty in Michigan, though we find in the East Saginaw coal mine for instance, above the 3 feet 3 inches of coal at 147 feet a 4-inch rider at 128 feet 7 inches, and another of 1 inch at 104 feet. So, too, around Sebewaing, when the main coal is from 85 to 105 feet deep, we sometimes find a little rider at about 71 feet. In naming and correlating the seams I have found it convenient to entitle them thus, in descending order: Upper rider, Upper Verne, Lower Verne, Middle rider, Saginaw, Lower rider, Lower coal. I would not pretend however, that seams which I have thus named are always the same. I know well that my correlations are far from perfect. Nor would I imply that the seams called riders may not at times be thick enough to work. The East Saginaw mines may be on the Middle rider.

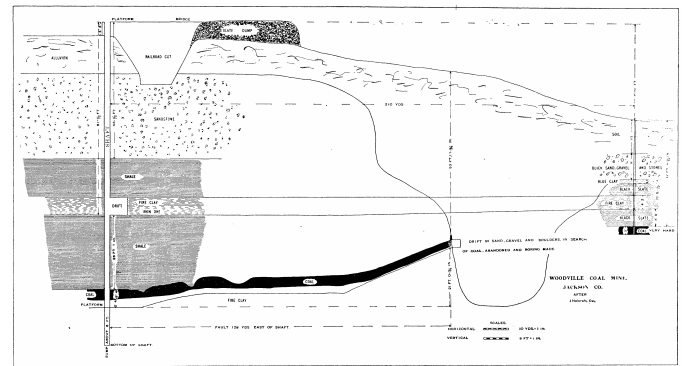


Figure 4. Section at Woodville Shaft. Illustrating the occurrence of a gravel filled channel or washout, and of undulations and pinches in the coal.

This law has been especially developed by Bain,* who gives a theoretical explanation of it, that the shrinkage and contraction of the lower coal bed, which if five feet thick represents about 60 feet originally of peaty matter, in slowly settling and compacting, made a basin in which the upper coal was formed. If his explanation is correct the phenomenon should be widespread, and the presence of riders is also alluded to by Nicoll† as a favorable sign. Thus we may safely say that the presence of small seams of coal is not unfavorable to more coal below.

*Iowa, 1897, pp. 299-300; Journal of Geology III, p. 646.

†Story of American Coals, Phila., 1897.

§ 8. Variation in coal measures.

No one bed of coal extended over all the coal basin.

This is obvious if we regard the coal basin as it now is, for many of the records like those of Alma, St. Louis, St. Johns and Ithaca, which are close to the center of the basin, show no coal. But this might be laid to the subsequent cutting out of the coal, just as the original East Saginaw well‡ struck a big sandstone which replaced all the coal measures down to 171 feet, including the bed at 147 feet which is now worked. But we find a number of the records in the center of the basin lacking coal, and though it is proverbially hard to prove a negative, on close comparison of the records it is hard to see how any one bed could have been represented all over the basin. We find the coal beds at all sorts of altitudes above the Napoleon from 163 feet at Sebewaing to 1,005 feet at Midland. The deep central wells show black shales and bituminous limestones! at horizons where coal appears at the sides. As Rominger says on this point,§ "Regularity in the sequence of strata does not exist in the coal formation. The beds in it are usually of local extent, so that a position which in one place is occupied by a shale bed may in a neighboring locality be filled by a ledge of sand rock." "The whole series is a constant alternation of shale and sandstone beds, every natural or artificial section teaches us that an immense variety exists in this alternation." Says Keyes,* "Few cases are at present known in which the

geographical extent of a workable coal stratum is more than four or five miles."

‡Geol. Sur. Mich., Vol. V, Part II, p. 55.

§Geol. Sur. Mich., Vol. III, 1876, Pt. I, p. 128.

*Iowa, 1894, p. 176.

Also Bain,† "Barren holes are frequently put down in the midst of productive fields, particularly in the Iowa-Missouri region."

We see therefore that we must not be discouraged by the failure of one hole in coal explorations, and on the other hand it requires much more testing to be sure how much coal we really have than it would if the coal were more regular. Bain's detailed sections‡ and our own on Plate IX show well how irregularly the coal is distributed.

In the same way, Orton, speaking of the Ohio coals, says that to expect the earlier formed seams in the center of the basin would be to look for the living among the dead,§ that in no case known does the coal extend beyond 600 to 800 feet below sea level, and "there is no instance known in which the Sharon" (one of the lowest coals) "has been found of mineable thickness directly under a mineable thickness of the Kittaning coals." "A coal seam can often be traced toward the interior of the field along some open valley, or by means of a series of test borings. In numerous instances such seams are found to suffer gradual reduction." Again (p. 135), "The later coals never extended over the outside margins of the earlier swamps. Of Missouri Winslow says,|| "No one coal bed in Missouri can be affirmed to be co-extensive with the area of the coal measures, and within a still smaller area does any one bed possess those characteristics of thickness and quality, or is it accompanied by the other conditions which go to make it workable." The "conditions" which he cites as preventing its workability are inadequate thickness, poor roof, disturbances which have produced faults—and faulty coal, inferior quality, excessive water, excessive depth.

Of these conditions the last, excessive depth, is not likely to occur in Michigan, except that where the coal is deepest the cost of drilling it up to see how much there is becomes excessively great. But once found in satisfactory quantity and quality the depth will never be a serious obstacle.

Examples of the running out of coal seams in our Michigan properties might be multiplied and it would be invidious to select examples. In one direction they very often pass into black shale, the transition being marked by bone coal or cannel coal.

†Iowa, 1897, p. 292.

‡Loc. cit., Plate VIII.

§Orton, Ohio, 1893, p. 262.

||Winslow, Mo., p. 33; see also pp. 24-25.

The coal is more abundant, not far from the margin of the large general coal basin. The coal beds

diverge and thin out gradually as they get deeper and lower coals come in. The remaining series thickens toward the center of the basin; in other directions they thin irregularly and suddenly.

Jackson and Sebewaing are on the extreme verge of the coal basin. At Williamston, Saginaw and Corunna, the basal sandstones are not much over 400 feet deep anyway.

Monitor is nearer the center. Wells still nearer the center at Lansing, St. Johns, Midland and Alma, have not shown much coal.

The irregular thickening and thinning in other directions has been touched upon under other heads, and will be referred to again when we come to treat of sandstone channels and bars. It may be noticed in reviewing the records of various explorations that the sudden disappearances of the coal have not been generally in the direction of the deeper part of the basin. In regard to other States in addition to what has been already quoted, Orton remarks:* "All of the coal seams below the Freeport horizon and a number above appear to have been formed as marginal swamps around the border of the sea," and the description of the Jackson county (Ohio) coal mines† that work in the Wellston coal which is "not more than 2½ miles wide and 7 or 8 long;" "on the northern edge of the basin;" rising "growing thinner" "down to a feather edge," "on the southern side" "running into shale and never met farther beyond," shows the mode of occurrence clearly. Winslow‡ gives a figure and frames his hypothesis to explain, "b. How coal beds are more abundant over the marginal area." What White says of the lower coals is quoted below.

*Ohio, 1884, p. 135.

†In Mines and Minerals, Jan., 1899, p. 254.

‡Mo., 1891, pp. 30-31; see also previous pages and p 52.

As to the question of the parallelism or divergence of coal seams, geologists have held very different opinions. Andrews, in Ohio, insisted upon the parallelism of coal beds (coal horizons) and Lesquereux held the same views, and both were experienced workers.

On the other hand, Stevenson and others have brought indisputable proof that coal beds have sometimes diverged from one main mass, and indeed Stevenson has suggested that a whole family of coal seams are but splits from one main seam. Keyes* has made a very plausible attempt at reconciliation in his supposition that the geologists who found a parallelism followed the coal along sections more or less parallel to the shore line of the great arm of the sea in which they were formed, while those who found a divergence studied sections running away from the margin of the basin. Certainly this applies to Stevenson's observations.

Let us see how Keyes' hypothesis will apply in Lower Michigan. The only part of the basin from which we have anywhere nearly enough data to test the matter is the southeast part between Sebewaing and Jackson.

In this direction the general trend of the coast in Carboniferous times was from southwest to northeast. Let us then first compare series of drillings and sections running in about that direction, in which the top of the Marshall sandstone is between 600 and 700 feet deep.

In the Bay City wells the Marshall is deeper,—in the very deep one at the works of the North American Chemical Co., the Napoleon Upper Marshall extends from 850 to 970 feet in depth. Gypsum is conspicuous about 130 to 200 feet higher, and the Parma or upper salt rock seems to be 360, extending between 490 and 540 feet. Immediately above is a thin stratum of coal near 480 feet. Now we have at Munger, through the kindness of Capt. Blodgett, a record which shows 60 odd feet of sandstone below 348 feet and a coal similarly just above it. This sandstone we may safely take to be the Parma, and we may infer that the top of the Napoleon would be about 700 feet deep. In the upper 350 feet we have not less than four coal horizons sometimes cut out by sandstones, the intervals being 16-90-52 feet. Between 140 and 160 feet are two quite persistent coals about ten feet apart.

*Iowa, 1894, pp. 164-171.

Passing now to the old first well of Saginaw put down by the East Saginaw Co., and recorded by H. C. Potter, we find the Napoleon sandstone at 637 feet, the first strong brines at about 487 feet (gypsum?) the Parma sandstone apparently from 293 feet 9 inches to 399 feet 1 inch, and no coal mentioned immediately above, but from 246 to 256 feet and from 229 to 233 feet were signs of coal. The upper part of the series is replaced by 78½ feet of brown sandstone. While this does not at first appear to match at all we find not far off at Crow Island a black soapstone resembling coal just above the Parma, and 44 feet above it a coal seam. Thus the lower seam is locally absent, and the second seam is the first met in the East Saginaw hole. A boring on C. K. Eddy & Sons' land 700 feet south of Genesee avenue, however, about a mile and one-half farther southwest, near which the Napoleon is struck at about the same depth as around the last well gives coal at 282 feet 3 inches and 203 feet 5 inches, and black slate at 196 feet, etc. The rest is cut out by sandrock. At South Saginaw where an old record with samples shows that the Napoleon is struck at 715 feet, and the Parma 375 feet above at 340 feet, bituminous black shales, occur from 305 to 318 feet—22 feet above, which may replace the lower rider and coal, while higher up at 180 to 200 feet is a coal reported in a great many records, apparently that mined at the Pere Marquette No. 2, the Chappell-Fordney, and the Riverside shafts. In the next seventy feet above are three coal horizons, the intervals in one case being 5-17-31 feet. So, down southeast across the Prairie Farm toward St. Charles, we find the Saginaw seam continues in spots, at somewhere about 190 feet, while above it are at least three coal horizons.

At Garfield there is an old salt well, now flowing. Though the lower salt rock is said to be 800 to 860 feet deep the upper salt rock with a very strong water is from 400 to

450 feet; while between them is said to be much lime rock. A recent well near by found two coals at 130 and 139 5÷6 feet which may be the Verne coals, and a mile and a half east the Saginaw coal comes in at 192 feet. At St. Charles a little farther on the Napoleon is about 700 to 810 feet deep. Below 500 feet is much hard lime rock. Above it is probably the Parma. At 425 feet it is said that there is coal, the lower coal horizon, while the main coal mined in five shafts around St. Charles is the Saginaw coal, from 180 to 220 feet deep. At 128 to 143 feet or thereabouts is quite a persistent vein of sulphury coal about two feet thick, and there are a couple of horizons still higher. (See Plate IX.)

Going into the Owosso district, we find to the northwest of it, comparing Rominger's and Winchell's account of the borings near the Detroit and Milwaukee station* and near Six Mile Creek, that there are from two (at 17 and 36 feet) to four coal beds near the surface, with one or two far down at 147 to 180 feet. Going still farther southwest to Grand Ledge, and putting together Rominger's descriptions of the outcrops and the artesian well of the Mineral Spring Hotel with Winchell's description of the explorations near Millett on Sec. 35, Delta T. 4 N., R. 3 W.,† we find from two to four coal horizons exposed by the river, and another coal seam some 73 feet below.

It is obvious that these sections do have a general resemblance and parallelism, though they differ in many minor details, which may to a certain extent be merely due to imperfect records. They all lie also in a general northeast-southwest line, roughly parallel to the margin of the basin.

If now we take a series of records lying in a line at right angles to this line, we shall find much more marked difference, so that it is extremely difficult to see the equivalent strata. Take, for instance, the fairly close series of records made by Durand‡ and the 907 foot and other borings around Corunna,§ the borings at the D. and M. Station at Owosso and four miles northwest by Mr. Courier on Sec. 57, T. 7 N., R. 2 E., also those of the St. Johns water-works well, and the wells at Ashley, Ithaca, and Alma and St. Louis. We find marked differences and divergences, extending down into the beds below the Coal Measures proper.

In the Durand well, it is probable that the water bearing strata from 174 to 238 feet under the brown shales represent some part of the great series of sandy strata beneath Corunna (on Sec. 22) from 231 to 471 feet.** This series seems to correspond to the whole series of sandy strata from 250 feet down to 601 feet in the well at Owosso (Sec. 5, Pl. XLV of Vol. V), which is, however, split by a series of limestones and shales that I take to be the Michigan series. These limestones and shales may in the Corunna well be represented! by marginal sandy strata, or not be represented at all according as the land margin was between Corunna and Durand or between Corunna and Owosso. In any case we have the Corunna sandstone series split once. Then passing from Owosso to St. Johns we find from 264 feet to 435

feet a series mainly of sandstones which must in some degree correspond with those from 250 to 473 at Owosso. Only 28 feet above we come to another sandrock which Winchell might call the Woodville. But the 26 feet of shale can hardly represent all the coal measure series. The shale may be another wedge splitting the great mass of shore sandstone. Then we pass on to Ithaca, which is quite a jump, partly bridged by wells near Ashley (which show down to 217½ feet mainly red sandstone, with coal and light and dark shale in the last few feet), and here we find a little red sandstone and shale near the top, but mainly a series of shales with five beds of dark limestone or black shale which might be taken as equivalent to coal horizons. Underneath this we have 86 feet of light-colored sandstone and then shale again. If we allow for a dip of not more than 15 feet to the mile, and we cannot well allow more, this Ithaca sandstone would correspond to that at St. Johns from 264 feet down, but is much less thick. In that case the St. Johns shale series has swelled and diversified enormously at the expense of the sandstone, and the Ashley well coal stands between the upper and lower sandstones at Ithaca. Then only six miles or so farther on we have at Alma and St. Louis some deeper wells which enable us to see quite definitely where we are. The Napoleon has shrunk from what it was in Owosso—from 65 to 47 feet. The Michigan series above it is characterized by gypsum beds as well as limestone, and is 225 feet thick instead of about 63 as at Owosso. Then we have the Parma sandstone well marked from 710 to 790 feet thick. Now, at 615 feet and 710 feet, are signs of coal horizons. There are two sandstones above it, separated from each other by blue and black shales. Is the lowest only of these three sandstones continuous with the great mass of sandstone to the southeast around Owosso? Probably not, for a dip of fifteen feet to the mile which is probably more than there really is, would make the sandstone at 637 to 675 run into that at 525 to 611 at Ithaca, and the same dip continued would make it split from the great sandstone at Owosso. But the uppermost sandstone, in the Alma well from 500 to 550 feet, and 300 feet down in the shallower St. Louis wells, may be the upper red sandstone of St. Johns and Ashley, and not appear at all around Owosso.

*Winchell, 1861, p. 125; also Vols. III and V of these reports.

†Winchell, 1861, p. 124; Vol. III of these reports, p. 133.

‡For farther details see the last chapter of this report.

§Geol. Sur. Mich., Vol. V; see also Rominger's and Winchell's Reports cited, and Lawton's Reports as Commissioner of Mineral Statistics.

**The reference in the record to hardpan and stones is probably to a conglomerate, for bedrock is usually struck at from 75 to 175 feet deep, and the water is higher in salt and lower in lime than shallower wells which are certainly in the drift.

If leaving Alma we pass toward the northeast, i. e., parallel to shore, we find at Midland a record which can be very closely paralleled with that at Alma.*

Turning to the coals; the couple of coals, often workably thick near Corunna, are represented by more numerous

coals, and some deeper coals near Owosso, which incline to be thinner. Near the center of the basin we have limestone in their place, and the coal indications appear above another large sandstone, which may correspond to Winchell's Woodville, or may be a split from the Parma, while black shales may represent some of the other coal horizons.

Thus we see indications of the kind of divergence that Keyes' hypothesis would lead us to expect.

The formations above the Napoleon are thicker in the center of the basin. But this is not simply by addition to the top of the series, but full as much by addition and expansions to the bottom of the series. The coal mined around the margin of the basin resembles in chemical character, that is per cent of sulphur and volatile hydrocarbon the higher coals of the center of the basin.

*Water resources of the Lower Peninsula of Michigan, U. S. Geol. Survey, 1899, Water Supply paper No. 30. Fig. 11.

§ 9. Low position of the Michigan coal seams.

Though the limestone underlying the coal series is equivalent to the Maxville in Ohio and the top of the St. Louis limestone of the Mississippi River, the age of the coal beds cannot be directly inferred inasmuch as there is generally an unconformity between it and the beds containing the coal seams. It is possible that near the center of the basin at such points as Midland, Alma and St. Louis the sedimentation may have been continuous, the Kaskaskia limestone being present as well as the St. Louis and the deposition of sediment being uninterrupted until the time of the coal deposits. This was not so at the margins. All the indications are, however, that all our series are low down in the coal measures (Mesocarboniferous), in fact in that section of it known as the Pottsville formation, "Serial conglomerate" or "millstone grit," a part of the series which was once supposed to be below any important coal seams, though it is now known that some of the best coals of the United States, the Lykens valley of Pennsylvania, the Pocahontas and New River of West Virginia, the Sharon, Massillon and Mercer coals of Ohio, belong to this series.

The evidence that our coals belong in this the lowest of the formations producing coal in commercial quantities is as follows: The fossil shells have been submitted to Dr. C. H. Girty of the U. S. Geological Survey who writes as follows:

"I have identified the following species:

Central Mining Co., Bay County.
Lingula mytiloides Sow.*

Wenona Mine, Bay County.
Lingula cf. Tighti Her.*

Verne Mine, Saginaw County.
Orbiculoidea sp.
Chonetes flemingi Nor. & Prat.*

Productus prattenanus Nor.*
Productus (Marginifera) muricatus Nor. & Prat.*
Orthoceras rushense McChes.
Soleniscus sp.

Michigan Mine, Bay County.

Lingula mytiloides Sow.*
Chonetes Flemingi Nor & Prat.*
Productus prattenanus Nor.*
Productus (Marginifera) muricatus Nor. & Prat.*
Avicula acosta Cox.*
Pleurophorus oblongus Meek.*
Nucula ventricosa Hall?
Trepostira sphaerulata Cow.*
Orthoceras rushense McChes.*
Large nautiloid.
Fish bone.

"The form which I identify as *L. mytiloides* has been so identified by Meek and many other American paleontologists. I am not sure that it is the same as Sowerby's species. The same is true of *Orthoceras Rushense*, the Michigan shells belonging to the form popularly referred, I fear incorrectly, to McChesney species. *Lingula cf. Tighti* may possibly be only young specimens of *L. mytiloides*.

"Regarding the age of this fauna I want to speak guardedly, for we have not been very successful in determining horizons in the Coal Measures by means of invertebrate faunas. The fossil plants seem to be much more reliable. As you observe, the list of species show essentially the same fauna at the only two localities where a fauna of any size was obtained. The invertebrates therefore afford no evidence favorable to subdividing these horizons into more than a single group. The species both as individuals and assemblages are such as are common in the coal bearing strata of Kentucky, Illinois, Iowa, etc., and in a general way indicate the same horizon for the coals of Michigan. This is not very definite, however. The age indicated is certainly older than the Upper Coal Measures of some writers, older than the Nebraska City beds of Kansas, for instance (See Meek's Pal. Eastern Nebraska, etc.). David White thinks the plants indicate Upper Pottsville, if I am not mistaken. We have very scanty faunas from the Pottsville and I have no reason to contradict his determination."

The *Lingula* shale has also been found,—identical in appearance, above the coal (with a *Discinisca*) at the Valley Goal Mining Company shaft, at the Bay No. 2, at the Wenona Air Shaft and at the Monitor, in all cases as I take it just above the Upper Verne Coal, as it is also at the Michigan Standard Mine. It has been identified at Grand Ledge and on the Rifle River. The richer fauna which occurs just over the lower coal of the Michigan Standard, the lower Verne, in a black bituminous shaly limestone, has also been identified over the coal of the Amelith Shaft of the Pittsburg Co. Rominger reports similar fossils from Jackson (p. 127) and Williamston (p. 135), and again over the upper coal at Corunna (p. 138). Dr. Girty we see does not feel that these species are

sufficient for close correlation, and it is well to remember that all the *Lingula* shales may not be at the same horizon though I am inclined to think it pretty persistent.

Both horizons are at times very close together, for instance in some parts of the Michigan Standard Mine, where the two coals run together toward the east. As Dr. Girty says, there is no indication of more than one horizon in the shells, which indicate quite clearly a marine or brackish fauna associated with those Verne coals. One cannot help being reminded of the upper and lower Mercer coals of Ohio. It is generally noticeable, also, that of the two coals associated with these fossils the upper is darker, less bright, with more charcoal and less pitchy layers, and though there are some sulphur balls it has less sulphur as a whole than the lower more lustrous coal, which contains more sulphur. All these facts indicate that most of the fossils come from one persistent not thick zone, that of the Verne coals.

The plant remains have been submitted to Mr. David White of the U. S. Geological Survey, who has been making an especial study of the remains of this epoch. He reports as follows:*

"These very incomplete and very fragmental floras interest me greatly, both on account of the fact that hitherto I have never seen else than *Calamites* (of little stratigraphic value) and *Stigmaria*, from the coal measures of your state, and by reason of the clues they furnish us to the age of the coals mined at the above named points.

"I have not had time to search for data on the relative positions of the coals or as to their group correlations. From the characters of the little flora I conclude that it can hardly be later than the Lower Kanawha in West Virginia, of the Brookville coal in Ohio and Pennsylvania. In fact, notwithstanding the small number of species I am strongly disposed to regard the plants from the Standard Mine as Pre-*Allegheny*, or at least older than the Brookville coal. On the other hand, they are not older than the Sharon coal.

"The little florula in the nodule from the Owosso Coal Co. points strongly to a place in the Upper Pottsville, i. e., the *Sewanie* zone. There are not enough species to tell whether it is so low as the Sharon coal. I would suggest a comparison of the horizon with the Mercer group. It is not likely to be higher than the group if so high.

"From the above you see that although the material is very fragmentary and the species are few, they indicate for the coals, at whose horizons they occur, a very low place in the coal measures; probably in the Sharon or Mercer groups for the nodules, while the Standard fossils seem to belong below the Homewood sandstone."

*The fossil lists returned by him are:

STANDARD MINE, SAGINAW.

- "1. *Sphenophyllum bifurcatum*, Lx.
2. *Neuropteris*.
3. *Calamites ramosus* Artis.

4. *Stigmara verrucosa* (Martin Mill.) *S. ficoides* (Brongn).
5. *Caulopteris* indet.
6. *Sphenophyllum cuneifolium* (Sternb. Teill) old form *S. Saxipojufolium*.
7. *Calamites* sp. indet.
8. Fragments of some fruit (*Cardiocarpon*?).
9. *Asterophyllites* cf. *longifolius* Sternb. (hardly determinable).
10. *Lepidodendron obovalum* Sternb.

GRAND LEDGE.

"The two fragments from Grand Ledge represent the same old early forms. *Sphenophyllum cuneifolium* (Sternb.) Teill." These are from the north pit of the sewer pipe works, near the level of the upper coal, the upper Verne? From the south pit as reported by the engineer of the works, Dr. F. H. Day, of Lansing, has in his collection.

19. *Lepidodendron lycopodioides* Stb. branchlets with *L. obovatim* Stb. bolsters. *Cordaites borassifolius* (Stb.) Ung. fragments and *Cardiocarpon Cuyahoga* (D. W.)
20. (6) *Neuropteris flexuosa* Stb., close to European type.
21. (16) *Neuropteris* cf. *Harrisii* D. W. (*N. rarinervis* group) with *Asterophyllites* Sp.
22. *Diplothemna* Sp.
23. *Lepidodendron obovatum* Stb.
24. *Pseudoplectopteris* (?) or *Mariopteris* (?), not enough for determination, for obscure nervation."

OWOSSO COAL CO.

I would like to suggest that good material, showing a much greater variety of species might be obtained by splitting off the more shaly external contacts of these nodules. The one which retained the contact shaly layers revealed.

1. *Cordaites*, probably *C. Robbii* Dn.
2. *Cardiocarpon ovale* Lx.
3. *C. bicuspidatum* Sterub. var. *ohioense* D. W.
4. *Mariopteris* sp. cf. *inflata* (Newb. Mss.).

ST. CHARLES.

The following forms are from the various shafts at St. Charles, and almost all from that of the Michigan mine (Black Pearl Coal), and immediately above or below the lower coal, the Saginaw seam. A similar *Lepidodendron* flora is found at the shaft of the St. Charles Coal Co., above and in the splits of the coal.

1. *Lepidodendron modulatum* Lx., St. Charles.
2. *Lepidodendron dichotomum* Stb., St. Charles.
3. *Lepidophyllum cultriforme* Lx., St. Charles.
4. Macerated fragments of plants with spores and slickensides resulting from collapse of some soft body, probably the fleshy envelope of a fruit.
5. *Calamites* cf. *cistriformis* Stur, with *C. Suckowii* Brongn.
8. *Lepidophyllum cultriforme* Lx. Black Pearl Shaft, St. Charles. This is an old type.
9. Axis of *Lepidostrobus* cone probably belonging to the same species.
10. *Lepidostrobus*, apex of, probably belonging to the same species.
- 11, 12 and 16. *Lepidodendron ophiurus* Brongn; St. Charles.
- 13 and 15. *Lepidodendron rhombicum* Stb. (*L. lycopodioides*) Stb., St. Charles.
14. *Lepidophloios*? decorticated and undeterminable, St. Charles.
- 7, 17, 18 and 25. *Stigmara verrucosa* (Mart) S. A. Mill, main segment.
26. *Pseudoplectopteris*? cf. *obtusiloba* (Brongn) Lx., J. H. Somers. No. 2 Shaft, St. Charles.

Dr. White also suggests a comparison of the Grand Ledge coal with the Mercer coals. I had already incorporated in the Mss., before receiving his letter, a comparison of the Verne coals with the Mercer coals, and all the evidence goes to show that the Grand Ledge coals correspond to the Verne coals.

The following correlation table may be of service, remembering that the Michigan correlations are very

hypothetical as yet. But in a general way I assign the mines as follows:

Upper Verne: Wenona and Handy Bros., upper part; Central, seam not worked; Michigan Coal and Mining, seam now worked; Valley, Monitor, Bay, Wolverine(?), Verne, upper part; Owosso Coal Co., Grand Ledge and Williamston, upper seam.

Lower Verne: Wenona and Handy Bros., lower part; Central, Michigan Coal & Mining, first seam; Amelith shaft; Corunna Coal Co., Sebewaing; Grand Ledge, coal mainly worked; Williamston, Jackson.

Middle Rider, possibly the East Saginaw coals.

Saginaw seam, Pere Marquette No. 1 and No. 2, Standard, Saginaw, Chappell; Fordney, Riverside, Jamestown, Robert Gage, J. H. Somers, No. 1 and No. 2, Black Pearl, St. Charles Coal Co. The coals below this are not worked.

Regarding the abundance of plants in a broad and general way, White, speaking of the Pottsville, says (1891, p. 180): "The fossil contents are also different from those of any sandstones above, since here for the first time in descending the column of rocks do we find *Sigillaria* and the large *Lepidodendron* very abundant in the sandstones." Now at the Sebewaing, Saginaw and St. Charles coal mines I have noticed the prevalence of such forms and *Calamites* and the relative absence of ferns, and Rominger* noted almost exclusively such remains and the *Stigmara* or creeping stems of the same plants.

*Geol. Sur. Michigan, Vol. III, Pt. 1.

CORRELATION OF COAL SEAMS.									
Pennsylvania.		Ohio.		Michigan.		Mines and Shafts.			
District.	Pottsville, D. White.	Lykens Valley.	Earlier Names.	Newberry.	Orton.	Base of Coal Measures proper.			
	Upper Intermediate Beds N and M.	Twin coal.	Homewood Sandstone.	Putnam Hill No. 4 coal. Brookville.	Lower Clarion.	Tionesta. Upper rider coal.			
	Beds J, K, L.	Lykens Coal No. 1.	Copaquenessing Sandstone.	No. 3a.	Upper Mercer Limestone.	Lingula shale. Upper Verne coal. Lower Mercer. Massillon sandstone. { Most of the Bay county mines, Sebewaing, Verne, Owosso, Grand Ledge, Williamston, Jackson.			
	Upper Pottsville formation.	(Sewanee zone in Tennessee.) Lykens coals No. 2 and 3.		No. 3.	Lower Mercer.				
	Beds H, I.				Massillon sandstone.				
	Lower Intermediate Zone.			No. 2.	Wellston Jackson Hill. Quakerstown.	Middle rider.			
	Beds E, F, and G.				Massillon sandstone.	Sandstone.			
	Lower Pottsville.			Sharon conglomerate.	No. 1 Briar Hill. Massillon. Jackson.	Sharon coal. Sharon conglomerate.	Saginaw coal.	Saginaw and St. Charles mines	
	Bed D.	Lykens coal No. 4. Brookside.					Lower rider.		
	Bed C.	Lykens coal No. 3. Big bed.					Lower coal.	(Lower beds toward the center of the basin.)	
	Bed A and B.	Lykens coal No. 5.							

In regard to this matter of the predominance of the rush and tree like forms of the lower coal measures we might cite many authorities. For instance, even over in Germany Geinitz divides the coal measures into three groups, which are, beginning at the top:

(1) Strata where ferns prevail: Upper coal measures.

(2) Strata where *Annularia* prevails,—a form which has a whorl of leaves around the stem, and *Calamites*,—rush-like form: Middle coal measures,

(3) Strata where *Sigillaria* prevails, Lower coal measures.

Finally there is a certain similarity in stratigraphy or mode of occurrence, for we find that the law holds for the Michigan coals as well as for the lower coals in general, that they occur in elongate local troughs, probably running each one in a general way toward the center of the basin, but as a whole occurring in a belt parallel to the old shore line and the margin of the basin.

The coal as it occurs in Sebewaing, at Corunna and at Jackson, seems to occur in troughs which are longest east and west or northwest. For instance we find that in the Woodville, the coal rose and ran out toward the Michigan Central track to the southwest. We find similar phenomena noted on other maps of Jackson coal mines. The trough of coal on Sec. 7, Jamestown, near Saginaw, also seems to follow this rule.

Pittsburg coal shaft at Amelith is said to be connected with the Bay Coal No. 2.

The Pere Marquette Mine No. 1 is understood to drain into the Saginaw mine, but to be separated from the Standard to the southwest by a sandstone bar. On the other side it is not far to the northeast before this particular seam plays out.

The directions of the troughs: are, however, quite variable, and we cannot yet lay much emphasis on this rule in Michigan. When we turn to the other States we find the evidence more decided. Prof. Sperr says of the lowest Ohio coal, the Sharon and Massillon that it lies in troughs.

Orton describes it as follows:*

"It always lies upon an uneven floor in basins of comparatively small extent. The area of but few of these basins reaches 200 acres of unbroken coal.

"It is everywhere a seam of 'swamp' and 'hills,' the latter rising 20, 30 or even 40 feet above the lower and more productive portions of the seam. In ascending these hills the coal rapidly loses height as a rule, and frequently disappears.

*Ohio, 1884, p. 156.

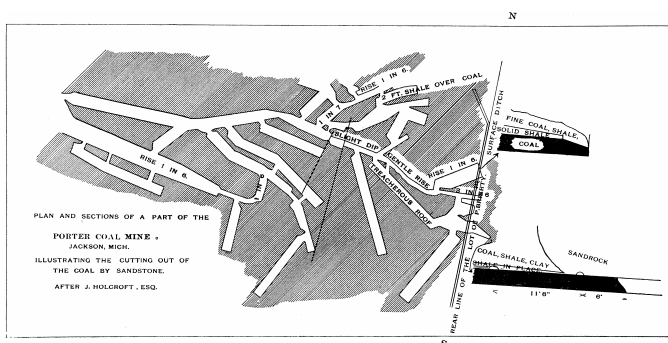


Figure 5. Plan of part of the Porter Coal Mine, showing irregular mining following trough and stopped by a washout or drift filled channel.

(p. 775.) "The Massillon coal occurs in lenticular areas of 30 to 70 acres, thickest at the center or axis of the swamp."

Again Bain and Leonard say (preliminary abstract of a paper before the Geol. Soc. Am., Aug. 25, 1898):

"The lower coal measures of the western interior field are marked by non persistence of strata. The upper measures are more regular. Between the two is a series partaking of some of the characteristics of each."

The same observation is made of the Indiana fields by Ashley in the 28th Annual Report, pp. 89 to 90.

And finally White remarks (1891, p. 180):

"The coals of the Pottsville series are persistent and valuable only around the margins of the Appalachian coal field."

It remains to be seen how far the coal strata of the center of the Michigan basin will show marks in their stratigraphy or plants of any later origin.

The two Verne coals may be traced, partly by stratigraphic comparison of record after record, partly by their chemical character, as coking coals, the lower one sulphurous, partly by their association with the Lingula shale, and calcareous beds full of marine fossils especially Productus, through the Bay county, Saginaw and Saint Charles fields, as I believe also in Owosso and Corunna, Williamston and Grand Ledge to Jackson.

If these are, as I believe, nearly equivalent to the Mercer coals, inasmuch as around Bay City they appear some 700 feet above the top of the Marshall sandstone, and may be traced more than half way to Midland with very little dip, it is quite possible that the 700 feet or more of strata above the base of the Parma sandstone at Midland belong wholly to the Pottsville formation, the extra thickness over sections elsewhere being produced by additions at its base. This is made more easy to believe, owing to the thick series of strata which Keyes has found elsewhere between the eocarboniferous limestone and strata of the age of the Pottsville.

Thus it seems to me at present most probable that the coal which occurs at about 136 feet around West Saginaw is at the same horizon as the coal at 85 feet around Sebewaing, and but little later formed as the marginal floating bog gradually crept out over the surface of the comparatively shallow arm of the sea, whose bottom was slowly sinking, which was, however, yet more rapidly filling up.

Keyes has recently published a paper on the Trans-Mississippian coals and their correlation.*

The Pottsville formation and the best known part of the Michigan series correspond to his Des Moines series. The unconformity between them and the underlying eocarboniferous limestone, which he calls Mississippian, and possibly also some part of the lowest beds in the center of the basin, represents his Arkansan series.

*Engineering and Mining Journal, June 1, 1901.

CHAPTER IV. ANALYSES AND TESTS OF COAL.

§ 1. Introduction and acknowledgments.

This subject which in the original report, issued in the Michigan Miner, was relegated to an appendix is treated more fully here. Numerous facts have accumulated in the meantime, the important series of tests made for us by Mr. H. J. Williams have been completed and we wish not only to help those who are having or should have analyses made to understand their value, but also to remove an impression which has been too prevalent, that Michigan coal is all of the same quality and that poor. Michigan coal is not all of the same quality and by no means all poor. Some of it (the Verne seams) is coking, some of it is not, some sulphurous, some (the Saginaw seam) not, and the heating power varies. Finally, Mr. Williams' results have a wider value, in fixing certain relations between heating power and analysis, which hold approximately true in Michigan at any rate.

I am indebted to Prof. F. S. Kedzie, of the Michigan Agricultural College, Lansing; Mr. H. J. Williams, of 161 Tremont St., Boston, Mass., for valuable help in the preparation of this chapter, and also for analyses and tests to F. F. Bradley of the Alston Manufacturing Co., A. N. Clark of the Alma Sugar Co., and C. H. Hilton, of the Agricultural College, Prof. C. A. Davis, of Alma, Geo. B. Willcox, M. E. of Bay City, and others.*

The following references will give the latest results and put one on the track of earlier works on this subject.

- (1) Phillips, H. J. "Fuels, solid, liquid and gaseous, their analysis and valuation;" London, Crosby & Lockwood, 5 sh. This is practically reprinted in the "Engineering Chemistry" of the same author and publisher, 1894.
- (2) Lord, N. W., and Haas, F. "The calorific value of certain coals as determined by the Mahler Calorimeter." Transactions of the American Institute of Mining Engineers, February, 1897 (Chicago Meeting), Vol. XXVIII, p. 259. In this same volume this paper is discussed by Wm. Kent and compared with earlier results, p. 946.
- (3) Slosson, E. E., and Colburn, L. C. "The heating power of Wyoming coal and oil." Special bulletin of the Wyoming University, Laramie, gratis. January, 1895.
- (4) Kent, William. "The calorific value of fuels," in Mineral Industry for 1892, p. 97, an annual published by the Scientific Publishing Co., New York, \$5.00, also in Vol. VIII, for 1899, pp. 124 to 129.
- (5) Fritzsche Dr. P. "Die Untersuchung und Bewerthung der Brenn stoffe," Leipzig, 1897.
- (6) Willcox, Geo. B. M. E. "Coal analyses—Their Objects and Uses." Michigan Miner, Vol. No. 4 (March 1, 1899), p. 19.
- (7) Hale, R. S., and Williams, H. J. "The calorific Power of Weathered Coal." Trans. Am. Soc. of Mech.

Engineers, December, 1898, Vol. XX, No. 798. Carpenter.

(8) Kerr, C. V., Trans. Am. Soc. of Mech. Engineers, Vol. XXI, No. 841, December, 1899. "The Berthier method of Coal Calorimetry."

(9) Christie, W. W. Trans. Am. Soc. of Mech. Engineers, Vol. XIX, No. 765, December, 1897, Boiler tests: Classification of data and plotted results.

(10) Hilton, C. H. "Sulphur and Iron in Michigan Coal." Michigan Miner, Vol. II, No. 9 (August 1, 1900), p. 9.

(11) Report of Committee on Revision of Standard Coal for Conducting Steam boiler trials, Vol. XXI. Transactions, Am. Soc. of Mech. Eng., No. 827 (December, 1899), and Discussions of same, No. 828.

(12) A new coal calorimeter by R. C. Carpenter; same transactions (June, 1895), No. 653.

There are also papers in Mines and Minerals, etc.

For the sake of those who have the works accessible, we may note that in the tenth census report (Gooch, Vol. XV, p. 775), and in the State Geological Survey reports, are many analyses, etc. (e. g. MM. of Pa.; Ohio, 1870, p. 236; Illinois, 1886, Vol.; Arkansas, etc.)

*Prof. Well of the Mechanical Department of the Agricultural College checked Plate II.

§ 2. Methods of testing.

Coal is principally used for producing heat. Its heat is mainly used for producing steam, and as thus used, the quality of the coal is naturally measured by the amount of water which it will convert into steam. In order to make this a definite quantity we must specify, however, how hot the feed water is, how hot the steam is and what the barometric pressure is. These will vary in different tests and reductions must be made accordingly, which are briefly noted below but are described more fully in mechanical text-books.

Whatever method of testing and of stating the results thereof is used, the results will be most easily understood by comparing them with some coal with whose behavior and, quality one is familiar. For this reason, we have included in the reports of the tests, those upon a number of coals mined outside the state, but commonly used within it, so that the results may be interpreted by comparison with them.

The methods of testing are as follows:

(1) Direct boiler tests, in which the results are stated in pounds of water evaporated into steam, per pound of fuel or per pound of combustible. The latter is generally obtained by subtracting the amount of ash,* and properly also moisture from the coal.

These are often tests of the boilers as well as of the coal.

(2) Tests of the coal, obtained in the instruments known as calorimeters, in which the amount of heat given off in burning a quantity is determined by absorption of the heat in water and measuring the rise produced. The results of these tests are stated in calories, i. e., the number of units (kilograms) of water which one unit (kilogram) of fuel will raise 1° centigrade, or in British Thermal Units (B. T. U.), i. e., the number of units (pounds) of water which one unit (pound) of fuel will raise 1° F. It is supposed to take 965.7† of the British Thermal Units to convert a unit of water at boiling point, into steam of the same temperature under average barometric pressure at sea level.

Pure carbon is supposed to give from 8080 to 8140 calories, that is 14,544‡ to 14,652.2 B. T. U. so that one pound might convert 15.1 to 15.2 pounds of water already boiling, into steam. Under ordinary circumstances of feed waters, etc., about half that amount per pound of combustible is obtained.

(3) The heating power may be very closely computed from what is known as an ultimate analysis and Dulong's formula, which is explained below, gives as good results as any:

(Heating power in B. T. U.) = $146 \times \% \text{ carbon} + 620 \times (\% \text{ hydrogen} - \frac{1}{8} \text{ oxygen}) + 40 \times \% \text{ sulphur}$.

(4) The heating power has also been estimated in various ways from what is known as a proximate analysis, but the formula which seems to give as good results as any of them for our Michigan coal** is, heating power in B. T. U. = $146.6 (x \% \text{ combustible}) + 40 (x \% \text{ sulphur})$.

(5) The heating power is sometimes computed from the reducing or deoxidizing power of the coal. This is known as Berthier's method and for a unit of fuel we recommend for our Michigan coals to apply a formula which I have derived on a following page: Heating power in B. T. U. = $423.4 (x \text{ amount of lead reduced}) \times 650$.

The last terms in these last two formulæ are fairly small, and the formula practically implies that the heating power is nearly proportionate to the % of combustible regardless of the relative proportions of fixed and volatile carbon. This is not accepted for coals in general and I do not wish to propose to extend these formulæ, except for our Michigan coals or so far as tests confirm them.

We will now proceed to consider these various methods of testing in detail after we have first considered the very important question how we are to get as fair a sample as possible of the coal for testing.

*If the coal contains much oxidizable iron, etc., this may give too low percentage of combustible.

†Or as 1 calorie = 1.8 B. T. U., 536 calories. See Plate II.

‡Fabre & Silberman, 14,544; Berthelot, 14,647.

**Provided the moisture is thoroughly driven out.

§ 3. Sampling.

A single lump is quite likely to be misleading. The heavier sulphur, slate and dirt tend to accumulate at the bottom of a pile, and in the finer stuff or slack. It requires some care to get a fair sample. Samples from well drillings are usually mixed with more or less clay from above. If that is washed out, as it usually is, it is nearly impossible not to wash away at the same time a certain amount of the pyrite (sulphur and ash), which occur in the coal. "At least five pounds of coal should be taken for the original sample, with care to secure pieces that represent the average, say the A. C. S. committee." In taking samples of worked seams, my own practice is to take about 25 pounds, evenly distributed from top to bottom of the worked seam. Very commonly in Michigan immediately above the main seam, is from 3 to 8 inches of poorer "bone coal," "cannel coal" or "slaty coal," sometimes improperly called black jack. This and the larger masses of pyrite will be kept out of the coal in mining and shipping, so far as possible, but more or less gets in especially in the run or slack. Care should therefore be taken to say whether these and slate partings were included in the sample or not. Thus the coal as shipped may possibly be somewhat better than a fair sample of the seam taken as above. It may also be poorer. My large samples were sent to H. J. Williams. He has some very ingenious arrangements for getting a true fractional sample. In general principle the material is run through a crusher and falls upon a sloping screen the bars of which are, however, hollow upwards and catch and conduct to one side a certain percentage of the material. The material which Mr. Williams did not use was returned to me and then fractioned very much as described by Fritzsche, and is preserved in sealed glass jars containing half a pound to a pound, for distribution. The samples when shipped to Williams and back again were not, however, in tight jars, but in stout paper bags inclosed in cloth sacks, and then boxed or barreled, so that there was opportunity to dry, and lose all superficial moisture.

Mr. C. H. Hilton's analyses show some desiccation that came since or in the later finer grinding of the material. The material thus preserved in jars is about pea or rice size.

The method of sampling recommended by Fritzsche* is as follows:

"Sampling is best done by an experienced hand as follows:

"From every cage or bucket of coal which is to be tested a shovel full is thrown into a separate bin. At the end of the sampling, the large pieces of the sample (which will weigh from 50 to 100 lbs.) are broken to nut size and the samples well mixed on a large floor or plate and the top of the pile pressed flat. Then with a smaller shovel, a narrow section is taken straight across and another at right angles. This smaller sample of from 5 to 10 lbs. is best sent in a tin lined chest to the analyst, who crushes still further and proceeds as above indicated two or three

times over to get a good average sample of 300 grams weight, in pieces the size of a millet seed. This sample is kept in a glass jar with tight glass stopper and used for determination of moisture after a quarter of the same is taken off in the same way and crushed to a fine powder and put in a separate bottle, for the rest of the analysis."

*1897, p. 48.

§ 4. Determination of moisture.

The first step in either an ultimate or proximate analysis is the determination of moisture. This determination is also commonly made in calorimeter* and other tests. For the moisture in a coal obviously does not help its heating power, and in the same fuel is liable to a good deal of variation depending upon the time it has been kept and the surroundings.

In this determination a sample of coal is first weighed, and then thoroughly dried. Gooch dried his sample over sulphuric acid 48 hours, weighed it, and then suspended it over water, but not in touch with it, 48 hours more and weighed again. The more common method is to heat nearly to boiling for about an hour (Phillips, and Lord and Haas, one hour at 100° to 105°C., Williams 45 to 60 minutes at from 105° to 107°C.), and the loss of weight is given as moisture or H₂O. To get comparable results the same methods must be employed. Probably it will be best to follow the rule of the A. C. S. committee: "Pry one gram of coal in an open porcelain or platinum crucible at 104° to 107°C., for one hour, best in a double walled bath, containing pure toluene, cool in desiccator and weigh covered."

Prof. Kedzie believes that more uniform results are obtained by drying the finely powdered material in vacuo over sulphuric acid.

It would be more accurate, but more expensive to collect the moisture and weigh it.

Kent has called attention to the fact that on heating the coal the weight decreases to a minimum, somewhere about 250°F., and then increases slightly (as the pyrite oxidizes?), and no loss of volatile matter occurs until about 350°F. His results have been confirmed by Carpenter and F. S. Kedzie.

This moisture is not merely wetness on the outside of the coal, although such would be included if there. But the samples which were sent to Mr. Williams, were so packed that they had a good chance to lose any superficial wetness, and after being returned from him were stored for sometime in a dry room, before being divided and sealed. Mr. Hilton remarks of them, that even then, while "the coals are to all appearances perfectly dry, yet when they are subjected to a temperature of 100°C. for half an hour they lose 5 to 10 per cent of their weight." So also Mr. Thomas Pray remarked regarding the amount of moisture in the sample whose analysis he furnishes (Table I, Nos. 3 and 4), that it was not superficial moisture. Almost all of the Michigan coal is under strong hydrostatic pressure,

except that around Grand Ledge. Coal is also somewhat hygroscopic. The lightness of the coal seems to be partly due to the moisture.

Especially care must, therefore, be taken to drive off all the moisture, and I think that many analyses of Michigan coal have failed in this respect. In boiler tests, for instance, it has been a common practice to set a pan of the coal not over three inches deep on the hottest part of the brick work for twelve hours. This method will not be at all satisfactory for Michigan coals. It gets rid of the "surface" or "accidental" moisture, but not the "characteristic" moisture, which may be sometimes reabsorbed from the air after being driven off by gentle heating, and is high in our Michigan coals generally.

In some coal high in sulphur and clay there is reason to believe that the low moisture returned is an analytical error, as will be later explained.

*Especially in using the Parr Calorimeter, see p. 73.

§ 5. Determination of ash.

Even in the common use of boilers it will be found of great practical benefit from time to time to make a trial run under average conditions, weighing the amount of feed water and coal used and of ashes removed, leaving the plant as nearly as possible in the same condition as found. Some results of tests of this character at the Lansing Municipal plant are given below ([p. 31]). Tests of percentage of ash are almost invariably made in connection with any heating tests as well as ultimate and proximate analyses.

The A. C. S. recommend determining this from the sample left after determining moisture, thus: "Burn at first over a very low flame with the crucible open and inclined till free from carbon," that is, until further burning makes no alteration in weight. If properly treated this sample can be, burned much more quickly than the dense carbon left from the determination of volatile matter.

The further determination of the constituents of ash is like the analysis of any rock, and several analyses are given by Phillips.

A complete analysis of ash is quite expensive, and the components determined are those usually determined in rocks, SiO₂, TiO₂, Al₂O₃, Fe₂O₃, (originally either sulphide, carbonate or oxide of iron) CaO, MgO, Na₂O, K₂O, CO₂, P₂O₅ (important in cokes for iron smelting) and H. J. Williams analyzes the ash for sulphur at any rate, in order by subtraction to get the volatile sulphur. It is well to analyze the ash in case the coal is to be used in Portland cement manufacture.

The oxidation of the iron and the partial separation of the CO₂, where the ash is largely CaCO₃, as Bradley reports to be true of a St. Charles sample, and Mr. Hess of a sample from the Corunna Coal Co., introduce errors in the process of burning, making the ash more or less than the substance from which it was derived in the coal,

but they are probably quite small, though I have seen crystals of gypsum on the surface of the Michigan coal, and veins of calcite and anhydrite. In very sulphurous coals as in No. A6 it may be apparent that if all the sulphur came from FeS_2 , all the ash must have too. For a given per cent of sulphur present in marcasite FeS_2 we shall have $\frac{7}{8}$ as much iron or $10 \div 8$ as much Fe_2O_3 in the ash. The ash will be greater than it should be by to amount equal to $\frac{3}{8}$ of the % of S. If half the sulphur remained after driving off the volatile combustible, the per cent of fixed carbon found by subtracting the % of ash from the residue left after driving off the moisture and volatile carbon will be $\frac{1}{8}$ of the S too large.

For instance in Williams' analysis of the Michigan Standard Coal Mine below (No. A9), if we suppose, as Hilton's work makes likely, that the volatile S is all in pyrite, this must have contained 4.98% Fe, equivalent to $(4.98 \times 10 \div 7)$ 7.11 Fe_2O_3 in the ash. Hence the ash (8.26%) found by analysis was almost wholly iron oxide. Instead then of the coal having an analysis of 6.09% moisture; 39.59% volatile combustible (including $\frac{1}{2}\text{S}$) 46.06 fixed carbon, and 8.26 ash, it should really be, supposing that the S were half driven off with the volatile matter, 6.09% moisture, 36.75% volatile hydrocarbon not including S, 10.66% pyrite, 1.15 ash and 46.35 fixed carbon.*

Hilton's work† indicates that the iron and the volatile sulphur are practically so closely connected that one may be inferred from the other, since they are in the same proportions as in pyrite, i. e., 7 of iron to 8 of sulphur. Thus an analysis for iron, one of the most simple and rapid of chemical operations, would be very nearly as instructive as the much more troublesome test for S. His results are given in Table D of analyses below and are shown graphically in the figure accompanying.

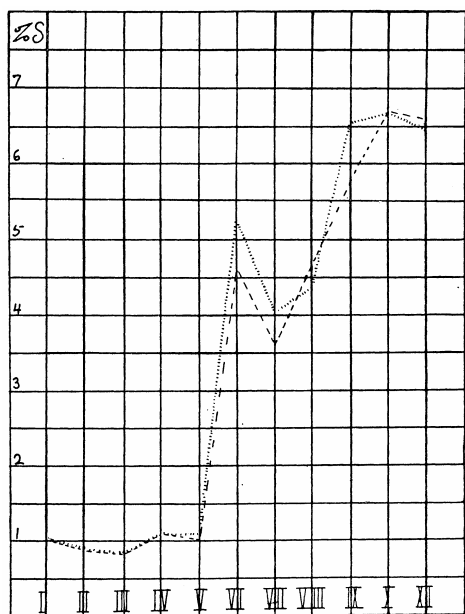


Figure 6. After Hilton, illustrating the connection between the sulphur and iron in the coal analyses of Table D. The line with dashes connects the percentages of S directly determined, the dotted line, the percentages of S computed as $8 \div 7$ of the iron.

*In some older forms of proximate analyses the sulphur was subtracted from the volatile matter or in part from the volatile matter and in part from the fixed carbon, half from each by some chemists or 60% from the volatile matter and 40% from the fixed carbon. This is not at all to be advised, since the proportion of sulphur which goes off with the volatile matter is uncertain, and varies not only with slight differences in manipulation, but also according as there is more or less of sulphur as sulphates in the ash.

†Reference on page 52.

§ 6. Determination of sulphur.

There is one constituent of so marked effect on the quality of the coal that an especial test for it is, and should be usually made, even in a proximate analysis, unless the method above suggested of estimation from the iron may in some approximate work prove satisfactory, and that is the sulphur.

Usually the coal containing the sulphur is burned in a closed vessel or combustion tube with one or another oxidizing agent to ensure complete oxidation to sulphates, and no escape of gas, and then the resultant amount of sulphates determined. If the amount of volatile sulphur* (sulphur combined as pyrite) is required the amount of sulphur or sulphates in the ash may be found and then subtracted from the total sulphates, but as the analyses show (Table A) the sulphur of the ash is usually only two or three tenths per cent.

This is the process adopted by Williams, who uses the method of analysis usually followed, known as Eschka's, thus described by Fritzsche:

"Weigh 1 gram of the same coal powdered in a platinum boat holding 30÷50cc. Add $1\frac{1}{2}$ grams of previously prepared mixture of 2 parts sodic carbonate and one part of magnesia, thoroughly mix with a platinum spatula and heat the crucible over a Bunsen burner turned down to a small flame so that only the bottom of it is faintly red, one hour, frequently stirring with a platinum rod. The reagents should be free from sulphates, which is frequently not the case, especially with the magnesia, even though it is bought as chemically pure. If the amount of SO_3 in the magnesia is known, a corresponding correction may be made in the result. To make sure of the complete oxydation of the organic matter as well as any sulphides that have been formed, add to the partially cooled contents of the crucible a few decigrams of finely powdered ammonium nitrate NH_4NO_3 , and heat once more in a covered crucible. Shake out the contents when cool into a beaker, wash several times with distilled water, and free any small quantities that stick to the vials, add to the wash water about 100cc distilled water to the beaker and boil about ten minutes. Put the cooled off solution with that which is undissolved in a 250cc measure glass. Fill up to the mark, mix and use 200cc of the filtered solution to determine sulphuric acid as usual."

Williams oxidizes with bromine in the presence of a little HC1 , and precipitates with BaCl_2 forming BaSO_4 .

13.789% of the $\text{BaSO}_4 = \% \text{S}$.

Fritzsche says that it is decidedly not advisable in order to insure complete oxidation that the sodic carbonate and magnesia be brought to fusion for some minutes, since in that case the silica of the ash is more or less dissolved and must be removed with much loss of time before the sulphuric acid determination can proceed.

Mr. Hilton proceeded as follows, using a modification of Eschka's method:

"A weighed portion of coal (1-1.5gr.) is intimately mixed with five times its own weight of sodium carbonate c. p. and placed in a flat bottomed platinum dish. The sample thus prepared is placed in a muffle, which, though hot, is still black. The furnace is so regulated that in half an hour's time the muffle will have reached a clear cherry red color. This degree of heat is maintained for another half hour, at the end of which time it is found that all the sulphur as well as all the carbon is entirely burned. The sulphuric acid displaced a portion of the carbonic acid of the carbonate, thus forming a soluble sodium sulphate. The remainder of the process is identical with Eschka's method.

"The sulphuric acid in the ash is made soluble by boiling the ash in a strong solution of sodium carbonate. The determination of the sulphur is then the same as in the whole sample."

Fritzsche also describes a method by which the combustible sulphur may be determined directly, the combustion taking place in a current of oxygen passing through a tube in which the coal lies in a platinum boat and is heated, the products of combustion being caught by being passed through two Peligot tubes filled with bromine and dilute HCl (or as he suggests H_2O_2 may be used if it can be obtained free from sulphuric acid). At the end when no more brightening glow of combustion can be obtained from the coal, the contents of the two tubes are thoroughly washed into a beaker, heated until bromine fumes disappear and into the hot solution of about 150 to 200cc, 2cc of a 10% BaCl_2 solution added. After a short boiling the precipitate is allowed to settle and the liquid above poured through an ashless filter, water is added to the precipitate and boiled again, and the precipitate brought upon the filter and washed with hot water until the wash water ceases to react for chlorine. The moist filter paper is put into a platinum crucible (folded together a little) and then burned to whiteness over a large Bunsen flame in a weighed open crucible. If the amount of BaSO_4 is but small the amount of the sulphate, which is reduced by the organic matter of the filter paper, is completely oxidized again after a short heating. If the precipitate is large and lumpy it may be well to moisten with some drops of ammonia sulphate c. p. and heat again.

*This will not be the same as the amount of sulphur volatilized in the volatile matter necessarily, for there is likely to be some fused pyrite left in the coke.

§ 7. Ultimate analysis.

The ultimate analysis consists in the determination beside the ash, sulphur and moisture already described, of the carbon (not including the carbon present as CO_2 in the ash), the hydrogen (not including that in the moisture), the nitrogen, and (*by difference generally*) the oxygen.

The coal is burned in a glass combustion tube as in the determination of volatile sulphur, in an atmosphere of pure oxygen, with copper oxide and lead chromate, and the products of combustion are collected separately, by being passed through a series of tubes: carbon as CO_2 absorbed by KOH, hydrogen as H_2O absorbed by CaCl_2 or H_2SO_4 . Nitrogen is determined volumetrically or by Kjeldahls' method, or the total acid product may easily be obtained in connection with the Bomb calorimeter test described below, and is sometimes ascribed to nitric acid. This would be quite inaccurate for our sulphurous Michigan coals, but if the sulphur is known the nitrogen may be computed.

Such an ultimate analysis costs about \$15.00 or \$20.00 and the heating power can be computed from it quite closely by Dulong's formula, as discussed below. It is to be noted that since the oxygen is determined by difference, any error in the other determinations will be reflected in it. If, for instance, the determination of ash is too large* that of oxygen will be too small.

*Through oxidation of the iron of pyrite, etc. If the earthy matter of the coal consisted largely of carbonates the error might be the other way.

§ 8. Proximate analysis—volatile combustible.

In addition to the determinations of ash and moisture, only one further determination is used in what is known as a proximate analysis, that of the volatile matter or volatile combustible as it is called. The endeavor is to estimate the hydrocarbons with part of the sulphur or that part of the coal which makes gas.

Comparable analyses of volatile matter must follow the same procedure, as various times and temperature give varying products and varying amounts of residue.

The A. C. S. committee procedure is:

Place one gram of fresh, undried coal in a platinum crucible, weighing 20 to 30 grams and having a tightly fitted cover. Heat over the full flame of a Bunsen burner for seven minutes. The crucible should be supported on a platinum triangle with the bottom 6 to 8 centimeters above the top of the burner. The flame used should be 20 to 25 centimeters high and burning free, and the determination made in a place free from draughts. The upper surface of the cover should burn free, but the lower should remain covered with carbon. To find volatile combustible matter subtract the percentage of moisture from the loss found here, the residue, if coherent, is the coke.

Lord and Haas heated 3½ minutes over a Bunsen burner, then 3½ over a blast lamp. The difference between this and the ash is called the fixed carbon.

It is clear that a proximate analysis is but a series of weighings and heatings. Thus:

	Loss is	Residue is
First heating to a little above boiling (under 250° F.).....	moisture.....	dry coal
Second heating, seven minutes until the smoky yellow flame ceases.....	{ volatile..... } { combustible.. }	coke
Third heating, until there is no more loss.....	{ fixed..... } { carbon..... }	ash

Practically, however, it is found best to find the moisture and ash from one sample and the volatile carbon from another, while the fixed carbon is estimated by difference. It is obvious that the sum of the percentage of the different components being always 100, if one is too large, for instance the ash, owing either to the fact that the coal was not completely consumed, or that the ash contained iron which was oxidized, then some other component like the fixed carbon must be too small.

The proximate analysis is much cheaper and simpler than the ultimate, and if a determination of sulphur is also made it may give us practically almost as much information as the ultimate. The heating power cannot be told from it quite so reliably in general, though from any one seam and district a formula may be obtained nearly as good, and as will be shown below, the formula,

Heating power in B. T. U. = 146.6 (total combustible; i. e., fixed carbon and volatile combustible) + 40 (per cent of sulphur), gives as good average results for Williams' analyses as Dulong's formula applied to the ultimate analysis.

§ 9. Nature of the volatile combustile or gas.

The volatile combustile consists as we have said mainly of illuminating gas together with certain impurities including much of the sulphur.

The hydrogen sulphide and carbon bisulphides, ammonia and other impurities of a tarry nature which are distilled in the volatile matter are deleterious to a fuel or illuminating gas, though of some value in themselves, and must be got rid of so far as may be. They cannot be eliminated entirely. To this end the sulphur is absorbed by quicklime, or by fresh ferric hydrate spread on sawdust, which recombines with the sulphur to form sulphide of iron once more.* It is common to estimate the purity of the gas by the number of cubic feet which will be purified by one bushel of lime. In Analysis I1 Pennock found per ton of 2,000 lbs. 19.16 lbs. of ammonia sulphate = .958% = 1.373 x the percentage of ammonia; also 110 lbs. of gas tar = 5.5% and 10,600 cu. ft. of gas. According to Winchell the Jackson coal yielded 8,000 cu. ft. per ton of 2,000 lbs. and 30 to 40 bushels of coke.

The ammonia is used extensively in producing soda from salt by the Solvay process, and in domestic use.

The gas weighs from half as much as air up, or about 30 cu. ft. to the pound.†

The following is a commercial report on a test of the Saginaw coal in gas production, made at the Keystone Tumbler Company, Rochester, Pa., in the Duff Continuous Water Sealed Gas Producers:

"Sixty-one tons of Saginaw coal operated the plant for six days continuously; no other coal used on the premises during the time of test.

"With Pittsburg coal, they used on an average of twelve tons every twenty-four hours to operate the plant, showing that sixty-one tons of Saginaw coal accomplished the same work as seventy-two tons of Pittsburg coal.

"At the end of the six days' run, there was less deposit of tar and gummy substance on the flues than is usual with local coal for the same length of time.

"There was less accumulation of clinkers and ash than with local coal for the same length of time.

"Comparison of Saginaw coal with best grade of Pittsburg coal, by analysis; from Pere Marquette No. 2 Shaft."

	Saginaw.	Pittsburg.
Moisture	1.98	.20
Fixed carbon	53.20	55.69
Volatile combustible matter	43.49	39.54
Ash	.87	4.05
Sulphur	.394	.52

Wuth & Stafford, who made the analysis, say:

"This is undoubtedly a good steam coal and we think it will do very well for producer gas. It requires a little different work from our Pittsburg coal and will take a little practice to find how to handle it."

They mean by this, that because of the high percentage of moisture, steam and air injected into the producers must be regulated differently.

The superintendent of the works where the test was made says: "The coal is better than we get here.

"We are of the opinion that the coal is suitable for gas making purposes and that it can be used with economy.

“(Signed) H. L. DIXON,
"No. 3 Wood Street,
"Pittsburg, Pa."

It will be noted that while they speak of the "high percentage of moisture" in the body of their letter, the analysis shows much less moisture than many of our analyses, but on the other hand more volatile matter. This is almost certainly due to a difference in analytical treatment.

Of these so called impurities of the gas, the coal-tar matters have, however, a very considerable value in themselves. In one case I was informed that a company offered to pay all the expenses of altering a coking plant which was letting them go, and guarantee a good price for the coke product, finding their profit solely in the coal-tar matters.

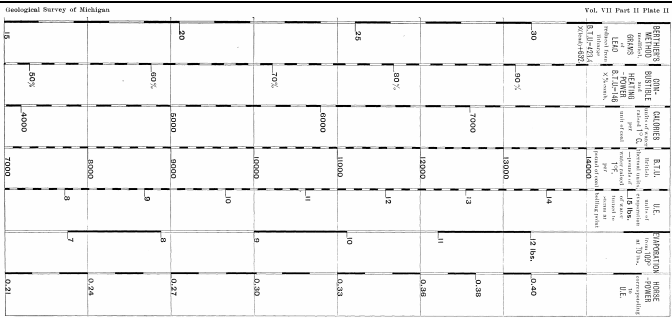
*Ferric hydrate is a waste product from purifying brine and sawdust a waste product of lumber. So that although the quicklime process is the more usual one, one would think the latter process might be economically employed at some points in Michigan.

†For analyses of gas, etc., see Mineral Industry, 1899, Vol. VIII, p. 147.

§ 10. Coke.

The residue after driving off the volatile matter or gas, if coherent, is called coke. But, according to the time, quickness and severity of the heating and amount of ash will more or less of the carbon and sulphur be retained. The coke contains, of course, all the ash.

The most called for coke should be clear, bright, hard, open textured, with but little sulphur and phosphorus, especially for iron manufacture. Its porosity may be tested by weighing it dry and then when saturated with water.



EXPLANATION OF PLATE II.

This Plate is intended to illustrate the equivalences in various expressions for the heating power of the coal, and also the heating power to be expected of the average Michigan coals, if it contains a certain per cent of combustible, column 2, or a certain reducing power, column 1.

For instance we see that if the burning of a pound of coal can raise 11,000 lbs. of water 1° F. the burning of one gram of coal can raise about 6,110 grams of water 1° C. A pound of such coal can then turn 11.4 lbs. of boiling water into steam, or 9.9 lbs. if the pressure is 70 lbs. to the sq. in. This is equivalent to a third of a horse-power per hour. For each horse-power per hour therefore if we use coal of 11,000 B. T. U. grade we must use three (times a factor which depends on the efficiency of the boiler and engine and is usually not less than two) pounds of coal. Such a coal would be a very low grade one for a Michigan coal, containing only 75.3% combustible, i. e. 24.7% of moisture and ash. Michigan coals generally run 13,000 to 14,000 B. T. U., that is the combustible is near 90% and the amount of moisture and ash not far from 10%. A gram of such coal we see from column 1 should reduce not far from 30 grams of lead from litharge, while the lower grade (11,000 B. T. U.) coal should only reduce 24.5 grams, supposing it to have the average composition of Michigan coals.

I have seen some nice looking coke made as an experiment from the Wenona coal, and it will be noticed that Mr. Williams reports a number of the coals as the coking coals. The coals which are thus coking are not, however, the lowest in sulphur, but as Dr. Koenig has remarked, by proper handling a large part of the sulphur may be driven off, so that but little will appear in the

coke. Ordinarily only about half of the sulphur is driven off, FeS₂ being changed to FeS. Tests have been made of the coke from a number of the Bay county mines. For instance, samples from the Valley Mining Company's shaft at Salzburg are reported to have yielded 39 bushels of coke per ton at the Bay City gas works. The coking coals seem to be the Verne coals.

§ 11. Heating power—practical test.

The full amount of heat that can be obtained from coal in a physical apparatus cannot be practically obtained under a boiler, where the combustion of coal is not perfect, as when there is incomplete combuston to CO, instead of CO₂, 11÷16 is lost. Also the gases escape hot and every per cent of moisture or of hydrogen burned to water in the coal that escapes as steam carries away much heat with it. The percentage of heating power actually realized depends not only on the coal, but on the perfection of the furnace draft and boiler. It is the highest where unburned air forms about one-third of the chimney gas, and has been found as high as 55% to 65% of the theoretically possible. For instance 7 Saarbruck coals which showed an average of 7,500 calories, i. e., should have evaporated 13.37 pounds of water theoretically, evaporated 8.17 practically (from and at the boiling point) and the heat was supposed to be distributed as follows:

	per cent.
Heat used in steam making	61.00
Ungenerated in combustible gases lost	5.5
Lost in hot clinkers and ash	1.5
Lost in hot products of combustion	5.5
Lost in smoke	0.5
Lost in evaporation of moisture	2.5
Lost in brick work	25.5
	100.00

We notice that the tests quoted by Mr. Willcox give similar results for the Michigan Coals, from seven to nine pounds actually evaporated, or from and at 212°F. from 9 to 12 pounds. And Mr. E. C. Fisher's test given below (p. 67) gives about 7 pounds actually evaporated, i. e., 8.63 lbs. per pound of combustible, or 59% of that given by Pennock's Calorimeter test, showing that the boiler was doing good work. The commercial evaporation is by convention fixed as the evaporation from a feed water temperature of 100°F. to steam of 70 lbs. gauge pressure. In Plate II we have the various methods of expressing heating power arranged in scale side by side, so that equivalent expressions may be seen at a glance. The commonest methods of expressing heating power are in units of evaporation, i. e., pounds of water changed to steam at a temperature of 212°F., or British Thermal Units, i. e., pounds of water raised one degree Fahrenheit. The tests of Mr. Edmond A. Edgerton, superintendent of the electric light and water works, Lansing, run 5½ to 9 pounds evaporated. We must remember that to fully estimate the heat obtained from coal we must know how warm the feed water was and how many degrees it had to be raised to the boiling point. Again, the boiling point is not always 212°F., though it is popularly supposed to be so, but it is higher as the steam and atmospheric pressure increases. Finally, if the steam is superheated or contains moisture,

there is more heat used there. There are, therefore, a number of corrections to be applied before results in different boilers under different conditions are applicable. For instance the coal that would evaporate 30 pounds of water per hour (one commercial horse power), the temperature of the water being 100°F. and the steam pressure being 70 pounds, would evaporate 34½ pounds of boiling water under atmospheric pressure into steam of the same pressure. Even then conditions that cannot be exactly figured out, the different adaptability of different grates and draughts to different coals, and subsequent varying loss in smoke and chimney gases, in brick work, clinker and half consumed ash, and the different experience of different firemen in handling different coals are so important that results must be taken with caution, and are mainly used in showing what coal gives best results with a given boiler outfit. For this purpose they are very valuable and should be widely used. If one coal is 10 per cent more efficient than another, it means more than 10 per cent discount in price.

The conduct of a complete boiler test is the work of a mechanical engineer, and is surrounded by a multitude of minute precautions detailed in papers in the Transactions of the Mechanical Engineers referred to, which cannot be repeated here.

The following report of a trial by E. C. Fisher of the comparative value of Saginaw and Hocking Valley coal is a good illustration of a boiler test. It will be noticed that the Saginaw coal used appears to be a trifle less efficient than the Hocking Valley pound for pound, but considerably more efficient at the prices quoted.

TEST BY E. C. FISHER, ON ONE WICKES' PATENT WATER TUBE SAFETY STEAM BOILER.

Fuel—		Saginaw.	Hocking Valley.
Kind of coal.....			
Total amount consumed.....	Lbs.	6032.0	5808.5
Moisture in coal.....	%	5.5	8.
Dry coal consumed.....	Lbs.	5757.0	5518.08
	%	4.2	6.1
Total refuse.....	Lbs.	245.5	338.5
Total combustible.....	Lbs.	5511.5	5179.5
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.....	%	.75	.73

BOILER TEST—Continued.

	Saginaw.	Hocking Valley.
Economic Evaporation—		
Water actually evaporated per lb.....	Lbs.	6.93
Dry coal.....		6.99
Water evaporated per lb. dry coal from and at 212° Fahr.....	Lbs.	8.26
Water evaporated per lb. combustible from and at 212° Fahr.....	Lbs.	8.63
Rate of Combustion—		
Dry coal burned per sq. ft. grate per hour.....	Lbs.	25.5
Dry coal burned per sq. ft. water heating surface per hour.....	Lbs.	.363
Rate of Evaporation—		
Water evaporated from and at 212° per sq. ft. grate surface per hour.....	Lbs.	211.04
Water evaporated from and at 212° per sq. ft. water heating surface.....	Lbs.	3.00
Commercial Horse-Power—		
On basis of 34.5 lbs. water evaporated per hour from and at 212° Fahr.....	H. P.	137.9
Builder's rating.....	H. P.	144.0
Cost in coal to evaporate 100 lbs. of water from and at 212° Fahr.....	Cts.	14 4-10
Cost of coal per ton (2000 lbs.).....	Cts.	2.25
Water evaporated from and at 212° per pound wet coal.....	Lbs.	7.80
Efficiency of boiler.....	%	71.10

The following blanks, used by Prof. Well of the Mechanical Department of the Agricultural College, show the numerous items which should be noted in an accurate test. The Committee of the American Society of Mechanical Engineers give two forms for a standard test of boilers, the longer including 88 items, the shorter 33:

Description of Boilers for trial at.....	
of (No. and type).....	
Date.....	
(a) Type of Boiler.....	
(b) Diameter of shell.....	
(c) Length of shell.....	
(d) Number of tubes.....	Vertical.....
(e) Diameter of tubes.....	Horizontal.....
(f) Length of tubes.....	Vertical.....
(g) Diameter of steam drum.....	Horizontal.....
(h) Length of furnace.....	
(i) Width of furnace.....	
(j) Kind of grate bars.....	
(k) Width of air spaces.....	
(l) Ratio of area of grate to area of air spaces.....	
(m) Area of chimney.....	
(n) Height of chimney above grate.....	
(o) Length of flues connecting to chimney.....	
(p) Area of flues connecting to chimney.....	

Governing Proportions.

(a') Grate surface.....	Water.....
(b') Heating surface.....	Steam.....
	Total.....
(c') Area of draught through or between tubes.....	
(d') Ratio of grate to heating surface.....	
(e') Ratio of least draught area to grate.....	
(f') Ratio of least draught area to total heating surface.....	
(g') Water space (cu. ft.).....	
(h') Steam space (cu. ft.).....	
(i') Ratio grate to water space.....	
(j') Ratio grate to steam space.....	
3. Grate surface wide.....	long.....
4. Water heating surface.....	area.....
5. Superheating surface.....	

6. Ratio of water heating surface to grate surface.....	
NOTE.—Items correspond to A. S. M. E. Standard Report of Boiler Trials.	
Results of the Trial of (No. and type).....	

Boilers at.....	
To Determine.....	
1. Date of trial.....	
2. Duration of trial.....	

Average Pressures.

7. Steam pressure in boiler by gauge.....	
8. Absolute steam pressure.....	
9. Atmospheric pressure per barometer.....	
10. Force of draught in inches of water.....	

Average Temperatures, Fahr.

11. Temperature of external air.....	
12. Temperature of fire room.....	
13. Temperature of steam.....	
14. Temperature of escaping gases.....	
15. Temperature of feed water.....	

Fuel.

16. Total amount coal consumed (includes wood x 0.4).....	
17. Moisture in coal.....	
18. Dry coal consumed.....	
19. Total refuse dry.....	pounds.....
20. Total combustible (item 18 less item 19).....	
21. Dry coal consumed per hour.....	
22. Combustible consumed per hour.....	

Results of Calorimetric Tests.

23. Quality of steam (dry steam taken as unity).....	
24. Percentage of moisture in steam.....	
25. Number of degrees superheated.....	

Water.

26. Total weight of water pumped into boiler and apparently evaporated.....	
27. Water actually evaporated corrected for quality of steam.....	
28. Equivalent water evaporated into dry steam from and at 212° F.....	
29. Equivalent total heat in British thermal units.....	
30. Equivalent water evaporated into dry steam from and at 212° F. per hour.....	

Economic Evaporation.

31. Water actually evap., per pound of dry coal from actual pressure and temp.....	
32. Equivalent water evaporated per pound of dry coal from and at 212° F.....	
33. Equivalent water evaporated per pound of combustible from and at 212° F.....	

Commercial Evaporation.

34. Equivalent water evaporated per pound of dry coal with one-sixth refuse at 70 pounds gauge pressure from temperature of 100° F. (==item 33 x 0.7249).....	
---	--

Special.

35. } Dry coal actually burned per sq. ft. of grate surface per hour.....	
36. } Water evap. from and at 212° F. per sq. ft. of heating surface per hour.....	

Commercial Horse Power.

43. On a basis of 30 lbs. water per hour evaporated from a temp. of 100° F. into steam of 70 pounds gauge (==34½ lbs. from and at 212° F.....	
44. Horse-power, Builders rating at.....square feet per H. P.....	
45. Per cent developed above or below rating.....	
NOTE.—Items correspond to A. S. M. E. Standard Report of Boiler Trials.	

Very much less elaborate and yet quite instructive, in a comparative way, are the tests conducted by Mr. Edgerton, superintendent of the electric light and water works, Lansing, given below. In these tests a 12 hour run was made of each coal, and an attempt was made to leave the grates in the same condition as they were found.* The amount of feed water was measured and

the feed water kept at a constant temperature of 110°F. The boiler pressure is nearly constant, about 95 pounds to the square inch, and the coal and ashes weighed as shown. Of course there are many chances for inaccuracy. The boiler pressure was not absolutely constant; the variations of atmospheric pressure and the temperature of escaping gases and the dryness of the steam was not noted nor the coal which preceded on the grate, and this might make quite a difference. Most of the above factors, however, would make no material difference in comparative tests. And if we reduce for some of them the water actually evaporated to units of evaporation, i. e., that which would be evaporated from and at 212°F. we find somewhere near the following values:

	U. E. 1st Series.	U. E. 2nd Series.	U. E. 3rd Series.
Average of Hocking Valley coals.....	7.38	8.32	
Saginaw.....	7.23		7.32
St. Charles.....		8.16	7.41
Corunna.....	6.49		
Williamston.....	6.51		
Bay City (Upper Verne).....	6.94		7.56
Bay City (Lower Verne).....			6.75

While the figures of Mr. Edgerton for the heating value of the Saginaw and Hocking Valley coals are much less than those given by Fisher, the relative values agree almost to a per cent. ($8.32 \div 8.26 = 1.01$ and $7.38 \div 7.23 = 1.02$.)

The first set of tests were in 1898. Another set of tests preliminary to awarding the contract in 1899 were made up to June 11, 1899. In this two of the St. Charles coals were represented, the J. H. Somers Coal Company and the Michigan Coal Company. The average result (7.05 pounds actually evaporated=8.15 pounds from and at 212°F.), is just a little less than that of the two Hocking Valley coals ($7.197 = 8.32$ pounds from and at 212°F.), but practically identical with that found for the Saginaw Coal Company by Mr. Fisher.

In a third series from June, 1900, to February, 1901, the best result was about as before and the Somers Coal Company gave about the same result with the Saginaw on the first test, and in the same general proportion with other coals as No. 3 and No. 4 of the second series. The coal from the Michigan Coal and Mining Company is from the upper seam and not that analyzed as A10, which does not represent what they ship. This latter was first worked and was analyzed by H. J. Williams. The sample tested at Lansing is probably better represented by Analysis J3.

It is not safe closely to compare the series, as there is probably some difference in the plant which makes one set not comparable with the other. Though the results on the Pocahontas ($9.312 \div 9.229$) and Wellston ($7.622 \div 7.596$) check quite closely, the Hocking Valley coals ran much better the second year.

Lansing Water-Works Tests

LANSING WATER-WORKS TEST—FIRST SERIES.

	A.	B.	C.	D.	E.	F.	G.	H.
1.	Cedar Grove.....	Steam lump	8471	804	62581	7.387	\$2.45	6090
2.	Goshen Hill.....	Run of mine	10162	965	71433	7.030	2.25	6248
3.	Black Diamond.....	" " "	11106	1293	70875	6.381	2.26	5647
4.	Massillon.....	" " "	10407	808	72547	6.971	2.33	5932
5.	Hocking Lump.....	" " "	11163	949	74400	6.634	2.35	5646
6.	New River.....	" " "	18765	524	68471	7.852	3.20	4907
7.	Hocking Valley.....	" " "	10706	808	71618	6.689	2.31	5791
8.	Cedar Grove.....	" " "	10000	1048	65614	6.561	2.35	5583
9.	Hocking Valley.....	Pea	12845	1558	75332	5.864	1.94	6046
10.	Mingo.....	Run of mine	9689	682	71486	7.363	2.80	5261
11.	Jackson Hill.....	" " "	10327	513	71185	6.846	2.50	5477
12.	Riverside.....	" " "	9062	491	74280	8.196	2.60	6304
13.	Hocking Valley.....	" " "	11645	1021	74899	6.432	2.34	5497
14.	Saginaw.....	" " "	10734	895	67471	6.274	2.30	5703
15.	Corunna.....	" " "	1440	565	56590	5.633	2.25	5066
16.	South Side.....	" " "	7896	565	63076	7.988	2.50	6390
17.	Wellston Shaft.....	" " "	8405	120	64066	7.622	2.25	6775
18.	Pocahontas.....	" " "	7089	285	65428	9.229	3.00	6153
19.	Not known.....	" " "	10673	1097	65882	6.538	2.69	6317
20.	Williamston.....	" " "	11773	440	62355	5.659	2.40	
			10391		62015	6.021		

A. Name of coal. 110° F.=61.89 lbs. per cubic foot.
 B. Grade of coal. F. Pounds of water evaporated per
 C. Pounds of coal burned during the test. pounds of coal.
 D. Pounds of ashes. G. Price of coal delivered in bins.
 E. Pounds of water evaporated during the test; feed water temperature, H. Pounds of water evaporated for \$1.00.
 Michigan coals are italicized.

1. Bidder, E. J. Corbett. No clinkers; light brown smoke.
2. " Pittsburg & Wheeling Co. Light clinkers; smoke medium.
3. " Black Diamond Co. Clinkers bad; heavy, dark smoke.
4. " Pittsburg & Wheeling Co. Light clinkers; smoke medium.
5. " O. W. Shipman. No clinkers; light smoke.
6. " John Dalley. No clinkers; light brown smoke.
7. " " No clinkers; smoke medium. Compare Wilcox's test.
8. " E. J. Corbett. Clinkers and smoke medium.
9. " Ohio Central Fuel Co. Clinkers and smoke heavy.
10. " E. J. Corbett. No clinkers; very little smoke.
11. " John Dalley. No clinkers; heavy smoke. Compare Wilcox's tests.
12. " O. W. Shipman. No clinkers; very little smoke.
13. " Ohio Central Fuel Co. Clinkers medium; smoke heavy.
14. " Saginaw Coal Co. Clinkers and smoke medium. See other tests and analyses.
15. " Corunna Coal Co. Clinkers and smoke bad; steam hard. See other tests and analyses.
16. " V. R. Canfield. No clinkers; smoke medium.
17. " Milton Coal Co. No clinkers; smoke medium.
18. " V. R. Canfield. No clinkers; very little smoke. See 2nd series.
19. " Wells & Clear. No clinkers; smoke heavy.

LANSING WATER-WORKS TEST—SECOND SERIES.

	Grades of Coal.	Lbs. of Coal burned during the test.	Lbs. of Ashes.	Per cent ashes.	Lbs. of water evaporated during the test. Temperature of feed water, 110 deg. 62 lbs.= 1 cub. ft.	Lbs. of water evaporated per lb. of Coal.
	B.	C.	D.		E.	F.
1.	Run of mine....	11789	1142	11.2	74648	6.332
2.	Run of mine....	8929	892	10.0	83142	9.312
3.	Steam lump....	11558	868	7.8	78616	6.802
4.	Steam lump....	13150	1118	11.8	96552	7.311
5.	Run of mine....	11500	1545	13.4	81064	7.046
6.	Run of mine....	10335	1092	10.6	72938	7.672
7.	Three-quarter lump.....	10532	945	9.0	78132	7.432
8.	Run of mine....	10305	500	4.85	78906	7.596
9.	Steam lump....	905	905	9.0	70404	6.972
10.	Run of mine....	9825	885	9.0	75392	7.673
11.	Run of mine....	9340	740	7.9	69750	7.470
12.	Run of mine....	8608	670	7.8	69006	8.019

1. Montana Coal & Coke Co. Clinkers; not satisfactory to burn.
2. Castner, Curran & Bullitt, Pocahontas. No smoke or clinkers.
3. Michigan Coal Co., St. Charles, Black Pearl. Very light clinkers; heavy smoke. See tests, p. —
4. J. H. Somers Coal Co., St. Charles. Light clinkers; heavy smoke. See tests, p. —
5. W. H. Vance & Co., Kelley's Creek. No clinkers; heavy smoke.
6. M. A. Hanna & Co., Youghiogheny. No clinkers; smoke medium.
7. The Pittsburg Coal Co., Hocking. No clinkers; good burning coal.
8. The Milton Coal Co., Wellston shaft. Light clinkers; smoke medium.
9. Lowery Coal Co., Hocking, Congo. Clinkers and smoke badly.
10. Lowery Coal Co., Boomer, W. Va. No clinkers; light smoke.
11. The O. W. Shipman Co., Peerless, Cedar Grove. Very light clinkers; smoke medium.
12. W. H. Vance & Co., Massillon. No clinkers; light smoke.

LANSING WATER-WORKS—THIRD SERIES.—1900-1901.

	Date of Test, 1900.	Coal burned during Test.	Ash.	Per cent of ash.	Lbs. of water at 62 lbs. per 1 cubic foot.	Water evaporated with 1 lb. of coal.	Water evaporated for \$1.00
1.	June 8.....	10124	1041	10	58280	5.756	4343
2.	June 9.....	8995	730	8.2	65410	7.353	5056
3.	June 12.....	9640	1105	11	58590	6.077	4901
4.	June 13.....	9512	594	6.2	63116	6.635	4825
5.	June 14.....	8520	503	6.9	57350	6.731	5280
6.	June 16.....	10110	895	8.8	64480	6.377	5081
7.	June 21.....	9770	785	8.0	62992	6.447	5157
8.	June 22.....	9350	595	6.4	59210	6.332	5389
9.	Nov. 11.....	14026	1255	8.6	59604	6.536	5335
10.	Jan. 4.....	13033	1510	8.6	101982	7.890	6133
11.	Feb. 5.....	13916	3780	19.9	93370	5.346	5374
12.	Jan. 20.....	14890	1835	8.1	103168	6.928	5542
13.	Jan. 10.....	12970	1490	11.5	101122	7.796	5846

1. Sandy Creek.
2. Boomer R. M.
3. New Pittsburg R. M.
4. Milton Coal R. M.
5. Pittsburg and Wheeling.
6. Somers' Coal Co., St. Charles.
7. Somers' Coal Co., from different shaft, St. Charles.
8. Pere Marquette Steam Lump (No. 2 Shaft).
9. Michigan Coal and Mining Co. Steam Lump (upper seam).
10. Pittsburg Coal Co.
11. Silver Mather Co., Bay City.
12. Pittsburg Coal Co. No. 8.
13. Pittsburg Coal Co. $\frac{3}{4}$ coal.

The object of the foregoing section is to show:

First, what the heating power of our Michigan coals is likely to be.

Second, the importance and elaborate character of a thorough boiler test which will show the efficiency not only of the coal, but of the boiler plant,—such a test should be made by a trained mechanical engineer.

Third, the importance in dollars and cents and comparatively simple character of a test which will show the relative efficiency of different coals with same plant.

*This is known as the "Alternate method" and seems to be growing in favor compared with the old "Standard method" of starting a new fire for each test.

§ 11. Heating power by calorimeter.

Slosson and Colburn have described and illustrated Mahler's Calorimeter quite fully in the Wyoming bulletin, previously cited, which may be obtained gratis on application. It has been improved by H. J. Williams, in many important details ensuring greater accuracy, yet without modifying the general principle. One of his is in use at Johns Hopkins University and one set of analyses, Nos. A1 to A11, were made on a similar instrument. He has also made one for the United States in testing explosives.

The Mahler Calorimeter was also used by Lord and Haas, and in the test with Fray's Analyses (I3 and I4) at Cornell University.

The Mahler Calorimeter, even unimproved, is by far the most accurate method of testing the heating capacity of the coal, but it is also the most expensive. The Michigan Agricultural College have recently bought a Parr Calorimeter which we illustrate below (Figures 7 and 8), which is quite effective and much less expensive, a description of which will serve to explain the general method of making tests with other calorimeters. The method of making a test with it is as follows:

One gram of coal is weighed out, having been first pulverized so as to pass through a 100 mesh sieve, and dried at 105° to 110°C. (220°-230°F.). This is put into the body of a steel cartridge, A of Fig. 7, D of Fig. 8. To it is added 16 to 18 grams of sodium peroxide (Na_2O_2). The stem of the cartridge, C of Fig. 7, is screwed on. The whole is shaken and the little turbine fans or vanes shown in Fig. 8 attached by spring clips to the outside. The whole cartridge is then balanced on a cone inside a can (A of Fig. 8) containing two litres of water, 3 to 4° colder than the room. In this can a thermometer T is placed. On the top of the cartridge stem which projects from the indurated fibre insulation (B C), which surrounds the can, a pulley wheel slips, by which the

cartridge may be revolved 50 to 100 revolutions per minute, with any light motor.

The stirrer is set in motion by a cord around the pulley P, which runs to any light motor (Plate III) that will turn the cartridge some 50 to 100 revolutions a minute, and a water current is started down past the cartridge through E and up past the bulb of the thermometer T. After a short time the temperature registered by the thermometer remains so uniform that for a few minutes no change can be noticed, so perfect is the insulation afforded by the indurated fibre pails, B and C and the double lid with the air space between. Then down the stem E a piece of red hot copper wire one half inch long, is dropped. By pressing the top E of Fig. 7, which rests on a coiled spring the valve D is lowered so as to allow the wire to enter the chamber A, and start the combustion of the coal at the expense of the oxygen of the sodium peroxide. Heat is evolved and the mercury of the thermometer rises. In four or five minutes the highest point is reached, and the difference between the temperature before firing and after is, after subtracting 0.15°C. for the heat introduced by a piece of No. 12 copper wire one half inch long, in a fixed ratio to the heat in B. T. U. by burning a pound of coal. What this ratio is may ordinarily be best determined by a test on some standard substance, as there is some heat liberated by combination of the CO_2 and H_2O with the sodium oxide. For this purpose sugar charcoal or some other coal whose heating power has already been determined, may be used.

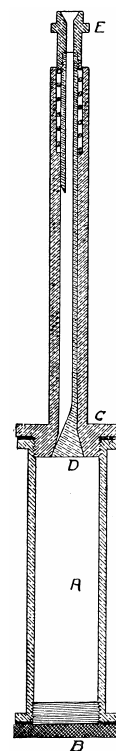


Figure 7. Cross-section of cartridge for Parr Calorimeter.—
See description in text.

The factor given by the manufacturers is 3,100.

The novel idea embodied in the Parr Calorimeter is the introduction into the combustion chamber and intimate mixture with the coal of a chemical, Na_2O_2 , which not only ensures complete combustion, but absorbs the gaseous products as fast as they are formed, so that enormous strength is not required to prevent their escaping, carrying heat with them. The test becomes rapid and inexpensive.

Now in the bomb calorimeter which is after all the standard, though much more expensive and difficult to manage, the general plan of operation is the same. But the coal is burned in an atmosphere of pure oxygen under pressure, and ignited by electricity. The gases of combustion are not allowed to escape, carrying the heat with them. In consequence the cartridge must be able to withstand an enormous bursting pressure. It is made spherical like a bomb. It has the advantage, however, that the question of the heat of absorption of the gases by the chemicals does not enter and that if need be, a fuel containing moisture can be accurately tested.

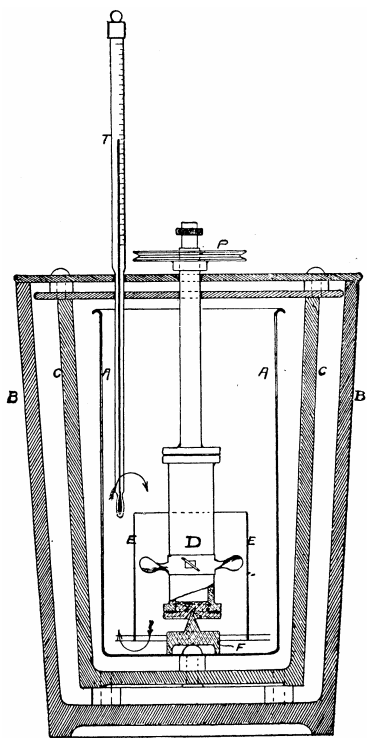


Figure 8. Cross-section of Parr Calorimeter.—See description in text.

Another rather simple form of calorimeter, the Barrus, is figured in the report of the committee of the Mechanical Engineers on Standard Boiler Tests.*

Another modern form of calorimeter is the Carpenter Calorimeter. This was also used in Fray's analysis and by G. B. Willcox for his tests at the University of Michigan and is described in the proceedings of the American Society of Mechanical Engineers.†

The Thompson and other older forms of calorimeter will be found described in most text-books and are still used, but are much less accurate.

*Transactions 1889, No. 827 so many times referred to, also 1893, p. 816.

†Vol. XVI (June, 1895), No. 653.

The determinations of the improved bomb calorimeter are the most accurate possible and are the standards by which every other test of heating power should be judged. Certain cautions must be given, however. As we have said it is not easy to get identical samples twice, and samples change slightly in keeping, the more finely they are ground.

Moreover, in practical work we shall never be able to reach the perfection of heat saving reached by the calorimeter. The degree to which we do this may be taken as measure of the goodness of the boiler arrangements, and as we have seen unless one is getting nearly 60% of the theoretical capacity, there is room probably for improvement in his boiler practice. Inasmuch as the calorimeter tests used to be expensive to make (\$25) and required the use of an expensive apparatus not readily accessible, other methods to obtain the theoretical heating power have been widely used.

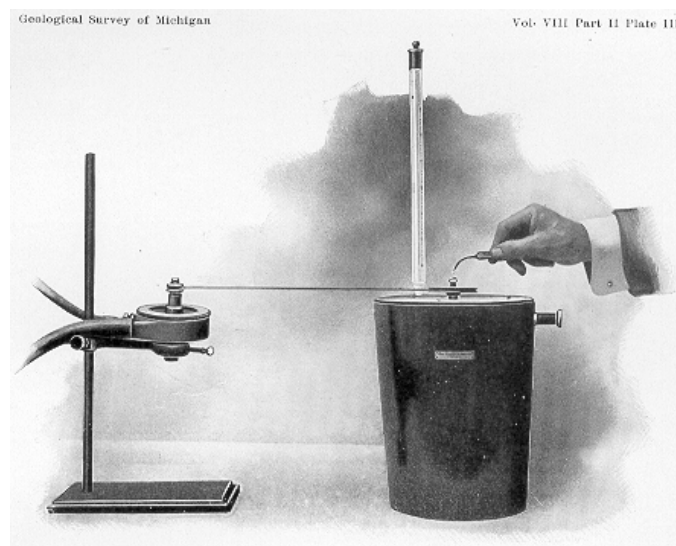


Plate III. The Parr Standard Calorimeter ready for ignition.

The following are the results of a series of tests for which we are indebted to G. B. Willcox, at the University of Michigan, with the Carpenter Calorimeter, published in part in the Michigan Miner, March 1.

The agreement with Williams' results is fair for Pocahontas coal, and for the St. Charles Black Pearl, compared with the St. Charles J. H. Somers No. 1. He gets considerably more out of the Pere Marquette and Saginaw than would be expected, unless they had lost quite a little moisture.

The object of introducing the series 12 to 23 is to show the variation of heating power with per cent of ash. Compare the Rifle River and Alpena analyses G4, 5, 7 and 8.* We see from the tests of Mr. Willcox that the heating power decreases in more than the ratio of the ash. Most of the material is from black shales or bone

coal. No. 23 is, however, a genuine coal, perhaps from the Lower Verne.

*Also D11, I11, J5 and 6, pp. 113 to 118.

Willcox's tests

TABLE—CALORIMETER TESTS OF G. B. WILLCOX.

No.		B. T. U.	Per cent Ash.
1.	Riverside.....	15,104	5.1
2.	Pocahontas.....	14,579	4.0
3.	Jackson Hill.....	14,196	7.45
4.	Jackson Hill, Big Drift.....	13,987	5.55
5.	Montana Lump.....	14,825	5.3
6.	Bellmore, W. Va.....	13,850	5.4
7.	New River.....	13,763	7.25
8.	Massillon.....	12,105	8.1
9.	Hocking Drift.....	11,935	9.33
10.	Jackson, Mich.....	10,070	9.1
11.	Jackson Hill.....	14,500	3.9
12.		8,884	37.8
13.		8,663	40.6
14.		8,618	42.8
15.		8,374	42.8
16.		7,967	42.7
17.	Tests of exploratory drillings near West Bay City.....	4,917	47.0
18.		5,133	47.7
19.		4,666	49.6
20.		9,125	23.
21.		9,633	23.
22.		6,866	36.
23.		12,500	9.5
24.	Saginaw Coal Co.....	13,000	3.25
25.	Pere Marquette.....	13,687	2.25
26.	Black Pearl, St. Charles.....	13,167	1.00

RIVERSIDE COAL. No. 1 of Table.

Mine located at Riverside, W. Va. Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, '97. Observer, I. C. Woodward, '97 thesis. Tested at U. of M. laboratory.

Preparation of sample: Has been stored in a dry place for several years. Sample obtained by a system of quartering.

Quantitative analysis made by A. R. Miller, B. S. (Chem.) '97:

Per cent of water	1.52%
Per cent of volatile matter	38.5%
Per cent of fixed carbon (plus fixed sulphur).....	56.07%
Per cent of ash	4.91%
Per cent of total sulphur	0.564%
B. T. U. in volatile matter	7,129
B. T. U. in fixed carbon	7,975
	15,104

POCAHONTAS COAL. No. 2 of Table.

Mine located in Wise County, W. Va. Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, 1897. Observer, I. C. Woodward, '97 thesis. Tested at the U. of M. laboratory.

Preparation of sample: Had been stored in a dry place for several years. Sample was obtained by a system of quartering.

Quantitative analysis made by A. R. Miller (B. S. Chem. '97):

Per cent of water	0.50%
Per cent of volatile matter	20.43%
Per cent of fixed carbon (plus fixed sulphur).....	74.07%
Per cent of ash	4.98%
Per cent of total sulphur	0.605%
B. T. U. in volatile matter	3,849
B. T. U. in fixed carbon	10,730
	14,579

See also test reported by R. C. Carpenter, Vol. XVI A. S. M. E.

JACKSON HILL COAL. No. 3 of Table.

Mine located at Jackson Hill, Ind. Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, 1897. Observer, I. C. Woodward, '97 thesis. Tested at U. of M. laboratory.

Preparation of sample: Had been stored in a dry place for several years. Sample was obtained by a system of quartering.

JACKSON BIG DRIFT. No. 4 of Table.

Mine located at same point. Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, 1897. Observer, I. C. Woodward, '97 thesis. Tested at U. of M. laboratory.

Preparation of sample: Had been stored in a dry place for several years. Sample was obtained by a system of quartering.

MONTANA LUMP COAL. No. 5 of Table.

Mine located at Fairmont, W. Va. Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, 1897. Observer, I. C. Woodward, '97 thesis. Tested at U. of M. laboratory.

Preparation of sample: Had been stored in a dry place for several years. Sample was obtained by a system of quartering.

BELLMORE COAL. No. 6 of Table.

Mine located at Bellmore, W. Va. Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, 1897. Observer, I. C. Woodward, '97 thesis. Tested at U. of M. laboratory.

Preparation of sample: Had been stored in a dry place for several years. Sample was obtained by a system of quartering.

Quantitative analysis by A. R. Miller:

Per cent of water	1.50%
Per cent of volatile matter	35.52%
Per cent of fixed carbon (plus fixed sulphur).....	58.4%
Per cent of ash	4.98%
Per cent of total sulphur	.756%
B. T. U. in volatile matter	5,440
B. T. U. in fixed carbon	8,410
	13,850

NEW RIVER COAL. No. 7 of Table.

Mine located at Fayette Co., W. Va. (Loup Creek). Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, 1897. Observer, I. C. Woodward, '97 thesis. Tested at U. of M. laboratory.

Preparation of sample: Had been stored in a dry place for several years. Sample was obtained by a system of quartering.

MASSILLON COAL. No. 8 of Table.

Mine located at Massillon, Ohio. Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, 1897. Observer, I. C. Woodward, '97 thesis. Tested at U. of M. laboratory.

Preparation of sample: Had been stored in a dry place for several years. Sample obtained by a system of quartering.

Quantitative analysis by A. R. Miller (B. S. Chem. '97):

Per cent of water.....	1.7%
Per cent of volatile matter	40.48%
Per cent of fixed carbon (plus fixed sulphur).....	51.2%
Per cent of ash	6.55%
Per cent of total sulphur	2.89%
B. T. U. in volatile matter	4,710
B. T. U. in fixed carbon	7,395
	12,105

HOCKING DRIFT COAL. No. 9 of Table.

Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, 1897. Observer, I. C. Woodward, '97 thesis. Tested at the U. of M. laboratory.

Preparation of sample: Had been stored in a dry place for three months. Sample was obtained by a system of quartering.

JACKSON, MICHIGAN, COAL. No. 10 of Table.

Mine located four miles from Jackson, Michigan. Sample obtained from the University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, May, 1897. Observer, I. C. Woodward, '97 thesis. Tested at the U. of M. laboratory.

Preparation of sample: Had been stored in a dry place about three months. Sample obtained by a system of quartering.

JACKSON HILL COAL. No. 11 of Table.

Mine located at Jackson Hill, Ind. Sample obtained from University of Michigan laboratory. Tested by Carpenter Calorimeter. Date of test, November 1, 1898. Observer, G. B. Willcox. Tested at U. of M. laboratory. Temperature of room 75° F.

NOTE.—This coal is very clear and free burning; no smoke from discharge opening from calorimeter.

Nos. 12 to 23 are of drillings.

SAGINAW COAL COMPANY. No. 24 of Table.

May 20, 1899. Sample submitted by Robert M. Randall, manager. Sample consisted of about ten pounds of medium and small lumps packed in tight wooden box. Received by express.

General appearance: Burns clear and bright. Steady pressure in the combustion chamber. No smoke emitted. Combustion ceases suddenly without glow and leaves a light feathery white ash.

PERE MARQUETTE MINE. No. 25.

May 20, 1899. Sample submitted by Robert M. Randall, manager Saginaw Coal Company. Sample consisted of about ten pounds of medium and small pieces packed in a tight wooden box. Received by express.

General appearance: Burns clear and bright. Steady pressure in combustion chamber. No smoke emitted. Combustion ceases suddenly without glow and leaves a light colored ash without perceptible traces of fusible matter.

BLACK PEARL MINE. No. 26.

May 22, 1899. Owned by Northern Coal and Transportation Company, St. Charles, Michigan. Sample consists of a single lump picked up at the mine. No attempt was made to get a representative sample by quartering, but the lump selected was in general appearance an average sample.

General appearance: Burns clear and bright in the crucible. No smoke emitted from the combustion chamber. At the close of the test the glow is suddenly extinguished, and the ash shows no appreciable tendency to fuse. Ash is light and feathery.

The low per cent of ash in this select lump illustrates what we have said about the ash being in the finer stuff and slack.

§ 13. Heating power by reducing power. Berthier's method.

This method is an old one introduced by Berthier in 1833 and used somewhat by Prof. F. S. Kedzie. Recently Kerr, as above cited, has tried to improve upon it, but has made an error in theory which we shall endeavor to correct and at the same time derive formula easily

simplified, yet sufficiently approximate for Michigan practice. Berthier's process is as follows:

Let the coal to be tested be intimately mixed with litharge PbO in the proportion of 20 to 40 (Berthier), or 50 (Kerr), of the litharge to one of coal and then placed in a crucible covered with a layer of PbO, and heated gradually. The coal will burn largely at the expense of the oxygen. Berthier assumed that all the combustible was carbon, but in reality we have, as Kerr remarks, hydrogen also, which gives out much more heat in proportion to the oxygen consumed. To see what the relation will be let:

x=amount of lead reduced by the weight of hydrogen h, changing to H₂O

y=amount of lead reduced by the weight of carbon c, changing to CO₂

z=amount of lead reduced by the weight of sulphur s, changing to SO₂

w=amount of lead reduced by the weight of iron f, changing to Fe₂O₃

$$x = \frac{206.9}{16} \cdot \frac{16}{2.02} h \text{ or } x = 102.42 h$$

$$y = \frac{206.9}{16} \cdot \frac{32}{12} c \therefore y = 34.48 c$$

$$z = \frac{206.9}{16} \cdot \frac{32}{32.06} s \therefore z = 12.93 s$$

$$w = \frac{206.9}{16} \cdot \frac{48}{112} f \therefore w = 5.54 f$$

$$z + w = 12.93 s + 55.4 \left(\frac{7}{8}\right) s = 17.78 s.$$

—if we assume, as Hilton's work shows that we may, that the sulphur and iron are combined in pyrite, so that we have f=7/8s. Assuming also, that heat of oxidation of the pyrite is 40 B. T. U. per unit of sulphur, of the carbon 14,600 B. T. U., and of the hydrogen 62,000 B. T. U. we shall have if P be the heating power per unit (gram) of fuel,

$$\begin{aligned} P &= 14,600 c + 62,000 h + 4,000 s \\ &= \frac{14,600 y}{34.48} + \frac{62,000 x}{102.42} + \frac{4,000(z+w)}{17.78} \\ &= 423.4 y + 605 x + 225(z+w) \\ &= 423.4 (x + y + z) + 181.6 x - 198.5 (z + w) \\ &= 423.4 (x + y + z + w) + 18,638 h - 3,530 s. \end{aligned}$$

Now (x+y+z+w), the total amount of lead reduced in grams is determined by experiment and the result obtained by neglecting the other two terms is Berthier's formula for the heating value. But omission of these two terms introduces considerable error.

Kerr also neglects the term containing s or z+w which introduces no very large error. Since, for instance, in our Michigan coals the sulphur of the pyrite runs from 0.82 to 6.67% the error made by neglecting the term containing s will average 113 B. T. U. and will in no case exceed 256 B. T. U. The term containing h is more important, and may amount to over 1000 B. T. U.

Kerr attempts to allow for this term 18,638 h by adding $\frac{18,638 h}{34.48}$ to the coefficient 423.4, and assuming a value

for h according to the class of the coal, .02 for anthracite, .05 for bituminous coal. Thus, for our coals P = 450 (x+y+z+w = total lead reduced), by Kerr's formula. Of course if an ultimate analysis has been made we could determine h more exactly, but in that case the heating value can be as well computed by Dulong's formula.

But this correction of Kerr's will obviously be approximately correct, only when x+y+z+w, the total amount of lead produced per unit of fuel is nearly 34.48, that is to say when the fuel is pure carbon or the amount of ash present balances the amount of hydrogen so that the reduction of lead is the same as though it were all pure carbon. A glance at his table shows that this is not generally the case. Usually it will fall short and in such cases his estimates of the heating power are short,* unless the hydrogen is overestimated.†

For our Michigan coals we see that the hydrogen‡ averages almost exactly .04 so that we may rewrite the formula.

$$P = 423.4 (x \text{ total lead produced}) + 623 + 18,638 (h - .04) - 3,530 (s - .0321).$$

The last term we can compute if the coal has been analyzed for sulphur. It may run 100 units more or less. The hydrogen term ought not to vary more than a couple of hundred units. Comparisons seem to indicate that even with this formula the lead method gives too low results. There are errors in other ways. For instance a certain amount of oxygen will be derived from interstitial air. If we may judge from Kerr's tests on sugar charcoal it may correspond to 260 B. T. U. The PbO is liable to contain some Pb₃O₄ and the iron instead of being oxidized may be alloyed with the lead. On the whole I think that the lead results even with this formula must be taken as minimum.

*For instance, in analysis No. 80 of his table I, if we assume 5% of hydrogen, a better estimate of the heating power would be about 12,900 instead of 11,915. It is easy to see that in his table II comparing oxygen and litharge methods, in treating pure sugar carbon or anthracite, his results will be in this respect nearly correct, while for bituminous slack, if my criticism is just, they may be, as indeed they appear to be about a thousand B. T. U. too low.

†For instance coals 19 and 110 which gave, with the Parr Calorimeter, 12,508 respectively, 13,438 B. T. U., reduced 27,397, respectively, 27.36 grams of lead per gram of coal used, i. e., 12,320 to 12,300 by Kerr's formula or by the one we have suggested, 12,223 B. T. U. the overestimate of the percentage of hydrogen compensating for the error in the formula.

‡Or rather the hydrogen effective in reduction (H — 1/8 O).

§ 14. Heating power computed from ultimate analysis.

The heating power of a coal is often stated in B. T. U. not per pound of coal, but per pound of dry coal or per pound of combustible, i. e., coal free from ash and moisture, and occasionally (so by Lord and Haas) per pound of fuel, minus ash, moisture and sulphur. The more the above constituents are eliminated the more nearly constant the heating power is found to be. Now, if we have an ultimate analysis of the coal there is a

formula known as Dulong's from which we can compute the heating power nearly as accurately as it is determined by a calorimeter. It is written in two or three different forms which are substantially the same. Lord and Haas use it in this shape:

Heating power in calories = 8080c + 34,462 (h — 1/8o) + 2250s.

c, h, o and s being the amounts of carbon, hydrogen, oxygen and sulphur in one unit of coal. For 8080 some use 8140; for o, o + n — 1. If the C is burned to CO, not CO₂, 34,462 must be replaced by 29,000. Sometimes 600 or 1000w (where w = moisture) is subtracted, but this must not be done in comparing with a calorimeter of the bomb pattern, as the hot gases are not allowed to escape.

Heating power = 14,544c + 62,031.6 + (h — 1/8o) + 4,050s, is the equivalent formula in B. T. U., but the boiler committee of the A. S. M. E. suggest the following form:

Heating power in B. T. U. = 146C + 620 { H — O / 8 } + 40 S.

Kent in Mineral Industry, 1899, for 146c writes 146.5c.

In this formula the C, H, O, and S, are 100 times greater than c, h, o and s, being percentages instead of fractions of unity.

We have calculated and find that for Williams' analyses A1 to A11, at any rate, no closer agreement with the result of calorimeter experiment is made by attributing any effect to the moisture. As regards the use of 1/8O instead of 1/8(O+N—1), 1/8(N—1) is respectively .05, .04, .05, .06, .03, .02, so that its effect is trifling, not exceeding 40 B. T. U., which is much less than the errors due to analysis and sampling.

Using the A. S. M. E. formula therefore we have (computing by slide rule) the following table:

TABLE.—COMPARISON OF WILLIAMS' CALORIMETRIC TESTS AND DULONG'S FORMULA.

Analysis Number.	Heating units by Calorimeter.	Computed by Formula.	Differences.		(H — 1/8 O)
A. 1.....	12,736	12,688	.....	— 38	3.64
2.....	12,868	12,876	+ 8	.....	3.84
3.....	12,896	12,506	— 390	.....	3.32
4.....	13,016	13,039	+ 23	.....	3.81
5.....	13,569	13,755	+ 186	.....	4.72
6.....	13,502	13,581	+ 79	.....	4.66
7.....	12,359	12,335	— 24	.....	4.24
8.....	12,861	12,702	— 159	.....	4.17
9.....	12,714	13,037	+ 323	.....	4.62
10.....	12,012	11,681	— 331	.....	3.79
11.....	12,099	12,035	— 64	.....	3.99
			+ 619	— 946	

The errors in excess and deficiency are almost equally balanced in number, but both in number and size of errors the computed heating powers are a little below those actually found. Thus, it is obvious that substituting 145.44 for 146 or any lower coefficient for C and H or introducing the term —1/8 (N—1) would not improve the agreement. Nor would it help to add the oxygen absorbed by the ash when the iron changed to Fe₂O₃ to the oxygen. But to use Kent's value for the coefficient of C, to-wit: 146.5 would make a distinct improvement, for

then the errors in excess and in defect would be practically equal.

It would help a little to assume that the iron in uniting with the oxygen gave out more heat than it absorbed in parting from the sulphur. But the discrepancies are not particularly in the S. No. A3, which is one of those most seriously out has but little sulphur, and the ultimate analysis shows nearly ½%, of hydrogen less than Nos. A1 and A2, while it has more volatile combustible. On the other hand the oxygen set down for A3 is considerably larger than any other analysis. As will be seen below, the results of computation from the proximate analysis check much better with the results of the calorimeter tests.

An error of less than 0.5% in the hydrogen would account for the discrepancy. Lord and Haas state the limit of possible error in an ultimate analysis as 0.5% in carbon and 0.2% in hydrogen.

In No. 9 also, where the greatest error occurs in the other direction the hydrogen is abnormally high and the oxygen low, and computation from the proximate analysis agrees quite well with the observed result. In No. 5, also, are the hydrogen and the computed value, high, and in No. 10 the hydrogen low and the computed value low.

Unless these errors, are due to errors in the determination of hydrogen, therefore, too much weight is given to the hydrogen.

If we plot the differences between computed and observed heating power referred to hydrogen, we shall find distinct indication that too much weight is given to the hydrogen. But taking the analyses of coals outside the state given for comparison we find no such indications, as we see from the following table:

	H — ⅙ O	Heating Power by Calorimeter.	Heating Power by Dulong For.	
C.1	3.41	12,885	12,620	— 255
C.2	— 4.04	13,867	13,565	— 302
C.3	— 4.49	14,572	14,514	— 58
C.4	— 4.22	14,880	14,748	— 132
C.5	3.12	11,074	11,413	— 261
C.6	3.71	13,151	13,297	+ 116
C.7	— 4.19	13,404	13,326	— 78

So that while we might add an empirical term to the Dulong formula and make the errors of more nearly even size, the improvement would hardly be sufficient ground for changing from the common formula, except Kent's change from 146 to 146.5, which gives a distinct but slight improvement.

§ 15. Heating power computed from proximate analysis.

Let us assume that we have determined volatile combustible v, fixed carbon f, sulphur s, and ash. We will assume as we found in testing the Dulong formula that the moisture and the ash have no effect. The fixed carbon we shall assume has the same effect as the carbon in the Dulong formula (though it really includes about ½ the volatile sulphur), and to begin we shall

neglect the fact that this is determined too low when the ash contains much oxidized iron.* The remainder of the carbon is included in the volatile combustible. The table below shows how nearly fixed the proportion of carbon is in the volatile combustible. We subtract fixed carbon of proximate from total carbon of ultimate analyses of Table A and find ratio to volatile combustible:

TABLE.—PROPORTION OF C. IN VOLATILE COMBUSTIBLE.

Analyses	A 1	2	3	4	5	6	7	8	9	10	11
C	71.11	71.67	71.37	72.88	73.55	72.42	65.87	68.33	68.07	62.29	63.59
Fixed C	53.95	53.80	52.58	52.96	45.28	44.64	41.16	45.15	46.06	41.67	42.16
Diff	17.16	17.87	18.79	19.92	28.27	27.78	24.71	23.18	22.01	20.62	21.43
Vol. C	33.14	33.59	34.74	35.70	46.73	46.59	38.45	39.79	39.59	39.62	40.57
Ratio	.518	.530	.540	.557	.605	.642	.582	.556	.550	.528	.528
Average	.561	±.04									

We see that the average is .561 ± .04

Thus, we may assign 146.5 x .561 = 82.2 ± 5.9 units to each per cent of volatile matter on the score of the carbon contained.

Next let us find the ratio of (H—⅙ O) to volatile combustible.

*As shown in table A, the error introduced by the S in the fixed carbon is insignificant.

The following table gives the ratio of H—½ (O+N—1) to volatile combustible for the first 11 analyses:

Analyses.	A 1	2	3	4	5	6	7	8	9	10	11
H	4.74	4.90	4.48	4.81	5.77	5.73	4.90	5.00	5.26	4.82	4.78
½ O	1.10	1.06	1.16	1.00	1.05	1.07	0.66	0.83	.64	.85	.79
H — ½ O	3.64	3.84	3.32	3.81	4.72	4.66	4.24	4.17	4.62	3.77	3.99
N — 1	.40	.30	.40	.45	.50	.50	.01	.25	.49	.20	.19
½ (N — 1)	.05	.04	.05	.06	.06	.06	.10	.03	.06	.03	.02
Vol. matter	33.59	33.80	33.27	33.75	46.66	46.60	38.45	39.79	39.59	40.57	39.62
Ratio Vol. m't'r	1.083	1.132	.0942	1.051	.0997	.0987	1.101	1.036	1.153	1.003	1.003

The average value of H—½ (O+N—1) is 4.03 or, including Dr. Koenig's analysis 4.00, of H—½ O is .04 more. The average value of the volatile matter is 39.00 and the ratio as we easily see is 0.104, just about one tenth of the volatile matter, so that we may also allow for each per cent of volatile matter 620x0.104=64.5 heat units on this account. Consequently we may in average assign 64.5x82.2=146.7 heat units to the volatile matter,—so nearly the same amount as the fixed carbon had that we may count it the same for both, say 146.6.

To the effect of the sulphur is hard to give theoretically even an approximate value. If there is oxygen added to the ash so as to make Fe₂O₃ out of the iron, and just enough iron is present to make FeS₂ then ¾ as much oxygen as sulphur is thus added to the ash, so that the chemist may estimate the carbon too low by that much.

We might accordingly allow and add for each per cent of S ¾ of 146 or 55 heat units on account of this deficiency in carbon. But on the other hand about half (the amount is not fixed) of the sulphur has been counted in the fixed carbon and allowed a heating value as though it were carbon. Accordingly ½ (146—40) or 53 units should be subtracted on this account. Thus, as we see in Table A, the net result will be almost no change. One might suggest that inasmuch as the sulphur is included in the

volatile combustible, in giving it any heating value apart therefrom, we were counting it twice and should deduct accordingly. But that is not true for the ratios to H and C of the volatile combustible were fixed, including the sulphur in the latter, and 146.7 heat units to each per cent of volatile matter is assigned on account of the H and C contained and not the S.

The Dulong formula assigns 40 heat units to the sulphur for its own combustion. It is not certain that the oxidation of the iron above mentioned really occurs completely. Ash is not infrequently magnetic. There may also be compensating loss of combined H from the clay, CO₂ from the calcite, etc. But on the whole we will take as an average formula for derivation of heating power from proximate analysis, if we use Kent's coefficient for the C, Heating power = 146.6 (f+v)+40s.

Plate II, however, was computed for 146 times various values of (f+v). To the heating value in B. T. U. as derived by Plate II from the combustible therefore it will be well to add about 100 B. T. U. for a coal which appears low in sulphur, and 200 for one high in sulphur, in case the sulphur is not exactly determined, to get the best estimate of the heating power.

In the following table the results of computation by this formula are compared with the results of tests with Williams' Calorimeter.

TABLE.—COMPARISON OF COMPUTATION FROM PROXIMATE ANALYSIS WITH CALORIMETER TEST.

	A. 1.	A. 2.	A. 3.	A. 4.	A. 5.	A. 6.	A. 7.	A. 8.	A. 9.	A. 10.	A. 11.
Total Combustible f + v.....	87.09	87.39	87.32	88.66	92.01	91.23	79.61	84.94	85.65	81.27	82.73
146.6 (f + v).....	12,778	12,823	12,812	12,997	13,487	13,374	11,644	12,452	12,536	11,914	12,128
40 s.....	44	40	40	90	113	123	119	153	239	266	277
B.T.U. computed.	12,822	12,862	12,852	13,057	13,600	13,497	11,763	12,605	12,765	12,180	12,405
B. T. U., Test.....	12,726	12,868	12,836	13,016	13,569	13,502	12,359	12,861	12,714	12,012	12,099
+ 96	— 6	+ 16	+ 41	+ 31	— 5	— 596	— 256	+ 51	+ 168	+ 306	
Ratio of f : (f + v)	.618	.616	.602	.597	.492	.489	.518	.532	.538	.510	.519

General average of A. 1 to A. 11 is .516
Average of A. 1 to A. 3 is 0.612 ± 0.010, probably the Saginaw seam.
Average of A. 5 to A. 6 is 0.490 ± 0.002, Jackson coal, the Lower Verne.
Average of A. 7, A. 10 and 11, 0.515 ± 0.005, Lower Bay City, the Lower Verne.
Average of A. 8, A. 9, 0.535 ± 0.003, both Verne coals together.

We see that the agreement with the calorimeter tests is in general quite as good as that of the Dulong formula, and in but one case is the error greater.

The cases where it does not agree are all coals high in sulphur and ash, yet no higher than others for which it works well. I think that in such cases it is more difficult to get true average samples.

Kent has constructed a diagram* to show how the heating power varies with the proportion of fixed carbon in the combustible (f+v), it being greatest when the fixed carbon is 80% of the combustible, i. e., about 158.4 (f+v). It would be according to his formula 146.6 (f+v) when f was 59% of f+v. This is close to the ratio for the first three analyses above from the Saginaw seam, where also the heat of the sulphur does not make much difference. For these analyses, therefore, our formula, which may be considered as an empirical adaptation of Dulong's is nearly accordant with Kent's. But for most of the remaining analyses, probably from the Verne seams,

Kent's formula would give results far too low. However, Kent remarks that his formula does not apply well and gives too low results in the case of certain gas coals where the fixed carbon is less than 58%, such as these Verne coals are.

Lord and Haas proceed a little differently. From f+v they subtract s, i. e., find the combustible free from sulphur, as well as moisture and ash. Subtracting from the heating power of any coal that fairly attributable to the sulphur, and dividing the remainder by the combustible, ash, moisture and sulphur free, we find the heating power of the latter which they call H.

$$H = \frac{P - 40 s}{f + v - s}$$

For Hocking Valley (Middle Kittanning) coal they find H=142.75 so that P=(H=142.75)x(f+v—s)+40s. See last row of table A.

We see, therefore, that their formula is very much of the same type as that we have derived independently from Dulong's formula, connecting the proximate and ultimate analysis of our Michigan coals, except that they have separated the sulphur entirely from the other combustible, which is theoretically correct, but practically inconvenient, and I doubt if there is any compensating increase in accuracy. At any rate no better agreement with the calorimeter tests appears to be obtained, and our formula can be applied more directly to the proximate analysis.

They have not allowed for increase in weight of the ash.

It is also to be remarked that the analyses of Williams upon which our formula is based (Table A) are exceptionally high in moisture and show more than is shown by other analyses of the same coals. Now it is quite likely that Kent's formula was based on compiled analyses in which the moisture was imperfectly separated from the volatile combustible, in which case we should expect that the volatile combustible would appear to have less heating power. For instance, in the gas tests at Pittsburg a sample of Pere Marquette No. 2 coal (F8) was returned as having but 1.98% of moisture and 43.49% of volatile combustible. It is reasonably certain that the coal is essentially the same as the coals of analyses A1 and A3, and the moisture imperfectly driven off. Clay and pyrite retard the departure of the moisture. Lord and Haas' determinations of moisture were also made at a lower temperature, and their determinations are probably less.

Moreover, in view of the fact that crude petroleum has a heating power of about 10,500 calories or 18,900 B. T. U., it would seem quite likely that the volatile combustible matter, if carefully separated from the moisture, would have as high heating value as the fixed carbon, so that the supposition that it has less is very likely due to imperfect separation of moisture from it.

It is, of course, true that a large part of the difference in percentage of moisture is due to actual difference in the amount contained in the coals. The more finely divided

it is the more moisture it seems to lose, the amount depending also upon the humidity of the atmosphere and the temperature and pressure. Prof. F. S. Kedzie finds that practically all the moisture is abstracted over sulphuric acid in vacuo, if the coal is finely powdered.

If we calculate the heating power of the sample analysis No. II the result will be 509 units in excess of the calorimeter result. If we apply it to Nos. I3 and I4, and assume one per cent of S, which is probably about right, we shall find the result nearly 1000 B. T. U. more than the calorimeter gave.

The calorimeter results of Nos. I3 and I4 are very low by any formula, or under any supposition, unless the heat carried off by the high percentage of moisture was not counted in. By comparison with analyses A1, I1, I2 and F8 on substantially the same coal we see how much the percentage of moisture varies, in the statements of different chemists.

*Mineral Industry, 1892 and 1900.

§ 16. Analyses and samples described.

(A). Analyses by H. J. Williams.

All our work has been based upon the eleven analyses made for us by H. J. Williams. It should be said at once that these samples are not put forward to represent the coal as shipped* necessarily, though in most cases they are intended to be a fair sample of the coal as it occurs in the workable seam. They were not intended to replace commercial analyses, but to give some idea of the variety of quality in Michigan coal, and if possible to serve as a basis by which one could from the proximate infer the ultimate analysis. This we have found that we can do in comparable analyses of the same set, but can in general only do with great caution, for different chemists seem to vary widely in drawing the line between moisture and volatile combustible, in these quite hygroscopic coals. Plate II gives a correlation of the different methods of expressing the heating power of coals, and also shows roughly what heating power may be expected from a given percentage of combustibles, or a given amount of lead reduced, in our Michigan coals, based upon Williams' analyses. Other analyses by other analysts all show less moisture relatively, but the heating power per unit of combustible comes out less, showing in all probability that the moisture was not so thoroughly separated in analysis, even if the coals had lost some moisture before analysis.

*In which the sulphurous part may be removed or slate by carelessness enclosed.

Analysis No. AI, from Pere Marquette Shaft No. 1, location, N. W. ¼ of section 32, Buena Vista township, T. 12 N., R. 5 E., about 300 paces S. and 700 paces E. of junction of Hess St. and Genesee avenue. The coal at the shaft rises in all directions, but rather rapidly to the east 14 feet or more and ceasing to have sufficient roof. A section of the seam is as follows from top to bottom:

Thin bedded poor coal ("bone coal").....	7¾ inches.
Slate parting	1¼ "
Top of coal rather sulphury, not so much so in all places	4 "
Main coal seam from which sample of about 25 lbs. was taken, about 50 yards south of the main shaft close to the south entry	32 "

A section of the strata near the shaft would be:

Clay	104	
Sand and gravel	3	107
Till (hardpan)	2	109
Good shale (slate) roof.....	19	128
Coal	3	131
Clay	1	132

The sample was taken by A. C. Lane April 15, 1899, reported June 26, reanalyzed by A. N. Clark (No. EI) about August, 1899, and again partially with iron determination about February, 1900, by C. H. Hilton (No. D1) with accordant results, and again later (reported August, 1900), by Reed and Bradley (H7 & 8). There has apparently been a gradual loss of about 4% moisture.

The Standard Mine (No. A2) is close by, though the coal m not continuous, being separated by a barren area, but the Saginaw Mine is in the same continuous seam (analyses F3 and I1 to 18), the water draining down into it as it is 12 feet deeper.

Analysis No. A2. From the Standard Mine, Saginaw, in the N. E. ¼ of Sec. 6, Bridgeport township, T. 11 N., R. 5 E.

The coal is 147 feet below the surface at the main shaft.

The following is the section as shown by the recent air shaft, which is south of the main shaft (Part I, p. 33):

Sandy clay	90	
Fine grained blue clay	10	100
Impure "fire-clay"	3	103
Shale, dark	8	111
Conglomerate	4	115
Black shale	20	135
Coal, about	4	139
Fire-clay (fern leaves)	6	145

Where taken there is 4 inches of top coal with more ash, and below 44 inches of the main coal seam which was sampled.

Though this mine is not two miles from the Saginaw and Pere Marquette No. 1 shaft, it is separated from them, I am told, by a barren area. At this mine the shales have a fair flora, referred to in the letter of D. White.

According to H. J. Williams' report, June 26, 1899, the coal does not swell up or coke, but cinters together and forms a hard cake; reanalyzed with iron determination February, 1900, by C. H. Hilton (D2).

No. H2, by F. F. Bradley, is from the same mine, but a different sample. The ash agrees closely.

Do not confuse this with the Michigan Standard Coal at Sebewaing. This is apparently the same coal seam as No. 1, and the analyses there cited should be compared.

Analysis No. A3. This is an anlysis of about 25 lbs. of coal from the J. H. Somers Coal Co., Shaft No. 1, at St. Charles, Sec. 5, T. 10 N., R. 3 E. J. T. Phillips, superintendent; F. G. Benham, agent. The coal rolls so much that considerable sections are exposed in the fire-clay and roof. The total exposed section being:

	Feet.	Inches.
Blue clay	14	
Hard bed, carbonates of iron		1½
Blue shale	3	
Low grade "Cannel coal"		3
Main seam (as sampled)	2	11

On the south side of the mine is more of the so called cannel, on the north side, none. A section at the shaft is:

Clay	28	
Sand and clay	3	31
Hardpan	9	40
Quicksand	2.5	42.5
Black shale	25	67.5
Gray shale	16.5	84.0
Sandrock	19.	103.
Shale	0.5	103.5
Coal (the Lower Verne?)	2.	105.5
Fire-clay	6.	111.5
Gray shale	8.	119.5
Black shale	4.	123.5
Fire-clay	4.5	128.0*
Gray shale	20.	151.0
Black shale	2.5	153.5
Fire-clay	0.5	154.0*
Black shale	25.5	179.5
Coal (Saginaw Seam)	3.5	182

We notice that beside the coal worked there is another coal at 105 feet which is said to be sometimes 2½ feet thick, more sulphurous and of inferior quality, dipping 4 feet in the 18 feet of the breadth of the shaft.

Taken April 13, returned June 26, 1899. Upon being heated the above coals, A1, A2 and A3, do not swell up and coke but cinder together and form a hard cake. Reanalyzed with iron determination by C. H. Hilton, February, 1900 (D3).

It has also been tested by the Parr Calorimeter (February, 1901) with results of 12,580 to 12,741 B. T. U., or when dried 12,663 B. T. U. The moisture of the sample has diminished to 5.59%.

Analysis No. A4 (B4 & D4) is of a sample from the mine of the Owosso Coal and Mining Co., R. E. Travis, proprietor, taken May 31st, 1899. The present shaft is about 40 rods east and 150 rods north of the old shaft, which I visited in 1895, in the N. W. ¼ of the N. W. ¼ of section 23, T. 7 N., R. 3 E. The section is as follows:

	Feet.	Feet.
Clay	7 to 8	7
Sand and gravel	15	22
Sand rock	35	57
Slate (hard shale)	18	75
Coal	3	78

Under the coal in part of the mine is the clay, in part quite sandy. The shales contain nodules of carbonate of iron with sphalerite and pyrite, similar to those found at Grand Ledge and at the Standard Mine. For a description of this clay see Vol. VIII, Part I, page 27. Mr. Travis had mined in all directions from the shaft over 400 feet at the time of my visit, controls 300 acres, paid 5 cents to 8 cents royalty, and was getting \$2.00 a ton for block coal, \$1.60 for nut coal. The mine caters to what may be called a local and retail trade, but has recently been sold to the Twentieth Century Portland Cement Company. The coals dip sharply to the N. E. as is shown by the fact that at the old shaft the coal is at a depth of only about 40 feet. This shaft is now used as an air shaft and an escape shaft. There is a break at the end of the south drift or entry, and the rooms to the west of it rise rapidly. Much water under a strong head comes in here. A bore hole going 75 feet below the coal gives a large supply of water with a strong head. The axis of the trough runs N. W. and S. E. Though this mine is near Kincaid's, it is said to be separated from it by a sandstone bar. This and the difference in quality lead me to think that they may be different seams; this one

the Upper Verne (compare A4 and I4), and the other the Lower Verne. The sample for analysis was taken from the east side, the section being as follows:

Black shale	10 inches.
Coal (perhaps upper inch belongs above)	2 feet 9 "
Sandy fire-clays.	

At the west end of the mine the section is somewhat as follows:

Shale with streaks of coal	8 inches.
Coal	32 "
Bone coal, "black jack"	7 "
Clay.	

There are fine *Stigmaria verrucosa*=*S. ficoides*; also *Sigillaria* and *Lepidodendron* at this mine, but no ferns were noticed.

From the nodules D. White has noticed *Cordaites robbii*(?), *Cardiocarpon ovale* Lx., *Cardiocarpon bicuspidatum*, Sternb. var. *ohioense* D. W. and *Mariopteris cf. inflata*, and infers a probable equivalence with the Upper Pottsville or Sewanee zone. At the old shaft the coal was dipping 8 to 10 inches in 2 yards, and there was a black shale (soapstone) roof full of impressions of reeds and pyrite. In the grey shale above it the zinc nodules occur. The section was:

Gravel or sand	16 to 26 feet.
Alternating grey shales and sandstones to	61 feet.
Black shale	2 to 3 ins. 61 feet 3 in.
Coal (2 to 4 feet)	2 ? 63 feet 3 in.
Fire-clay	12 feet.

Analysis No. A5 (B5) is of a lump from the New Hope Coal Mine, Jackson, the main seam. No. A6 (B6) is of the top part, which I was told was somewhat different, but as we see, proves not essentially so. This mine is about two miles N. W. of the city limits on the S. W. part of section 21, T. 1 W., R. 2 S.

The mine, though in a small valley close to a county drain, is nevertheless upon a moraine about 80 feet above Jackson city. The section exposed in the mine is as follows:

Black shale	top.
Top coal (analysis No. 6)	7½ inches.
Pyrite parting	1½ "
Main coal (analysis No. 5)	32 "

There is considerable variety in the general section, and the coal lies in troughs which roll quite irregularly and more markedly southeastward, while to the N. W. it flattens out and becomes more regular, but the coal thins out and passes into black shale. Fifty feet west of the shaft the section is:

Surface	40'	
Slate	39'	70'
Coal	3' 5"	82' 5"

To the east the coal becomes more hard and sulphury and I think runs up against a normal fault which strikes N. N. W. There are said to be a number of cases in the Jackson field and one in this mine where reversed faults occur with a very flat hade, so that coal is shoved over the coal. The coal lies in a narrow trough not more than 150 yards wide, and several hundred long, so that when twenty years ago a hole struck coal here, other borings put down to test up failed to find it, and the project was then abandoned.

The output is about 60 tons a day, and as there is no railroad to the mine, the market is purely local, much being used in harvesting. The royalty was ten cents per

ton on coal mined and sold. Screenings are not counted in computing royalty or wages.

The clay below the coal is soft for 4 or 5 inches, below that quite hard. A well is put down to 230 feet, mainly in white sandrock, with "soap rock" between that and the coal.

This is a coking gas coal (compare F7, G6, H4). I hardly think that Willcox's test No. 10, the exact location of which is not known, is of this coal.

Analysis No. A6 (B6) is of a lump from the top seam, which was supposed to be different. The high per cent of sulphur and low per cent of ash in this analysis made it seem probable that some of the sulphur was combined organically and not with the iron, as 3.07% S would imply 3.84% of Fe₂O₃ if the S all existed as FeS₂ and was all burned to Fe₂O₃. So I had it analyzed by Mr. A. N. Clark, and the iron especially determined, and though the ash is slightly more, the Fe₂O₃, as directly determined, would not yield enough iron to make FeS₂ with the S. It may be a question, however, in view of Hilton's results, whether there is not an analytical error, or more probably an irregularity in sampling. If the S and Fe are not determined from, identically the same sample, the pyrite is so much heavier than the coal, that it is not difficult to get ½% difference. It is clear in any case that almost all of the S and ash of the analysis came from the pyrite.

Analysis No. A7 (B7 and D5) is from the Lower Verne, part of the Wenona coal seam,—not the best part, compare Analysis A12, and Plate IV.

This coal has also been analyzed by Dr. Koenig. His analysis is of both seams, and is rather better than ours. I took mine from the lower seam (Lower Verne) intentionally to see if there was any marked difference in comparison with his, especially in coking capacity. Mr. Williams reports a coke of small volume, well fused and of excellent quality. It is a true coking coal.

Analysis No. A8 (B8 and D6) is from the Verne (formerly Albee) Coal Co., N. W. ¼ of N. E. ¼ of Section 23, T. 10 N., R. 4 E. The coals here mined resemble the coals of the Wenona, Central and other Bay county mines, and I take them to be the same. In both cases there are two seams of coal close together, in both cases immediately associated with black shale containing marine fossils. It will be noticed also that in ratio of fixed carbon to combustible, this and the other analyses, A5 to A11, which I assign to these same seams, differ 10 points more or less from the Saginaw seams, but only 2% from the average, or are at extremes 5% from each other. Both coals are coking coals, but the lower is brighter and has less charcoal but more sulphur. The section is as follows:

Putty clay.....	16'	
Till hardpan.....	22'	38'
Sand.....	2'	40'
Shale.....	25'	65'
Coal at a depth of from 50 to 60 ft.....	3¼'	68½'
Upper coal with much charcoal.....		34"
Slate.....		7"
Lower coal, brighter.....		6"
Fire-clay or shale below.....		

A well goes on to 75 feet and draws somewhat mineral water, while a well not far off has soft, not salty water at 107 feet.

Analysis No. A9 is of the Sebewaing coal, a large sample taken from the pile of the Michigan Standard Coal Mining Co. by Prof. H. Ries. They struck 4 feet 9 inches of coal at 92 feet depth and have from 7 to 17 feet of slate roof. Compare the records of numerous holes given in Vol. VII, Part II, in this neighborhood, and Figures 10 and 11 of that report, reproduced here as Figures 3 and 9. Analyses F1 and F6 are from other mines near by in the same seam, and agree in indicating considerable sulphur and a high percentage of gaseous matter.

Analysis No. A10 (B10 and D8) is taken from the mines of the Michigan Coal and Mining Co. (J. A. Etzold, Pres.), on the N. W. ¼ of the S. E. ¼ of Section 25, T. 14 N., R. 4 E. In this mine we have two coals, of which the lower was worked at the time of my visit (at present I understand the upper only is shipped), which was at an early date, Sept. 20, 1899, when the mine was only out 500 feet to E and not so far W. It is about 122 feet down through the lower coal. At the east end of the mine the two coals approach, and there is but three feet between them. The upper coal is more wet and gassy, but of better quality, apparently. See tests at Lansing; Water Works in 1901, and also J3. A section is as follows:

Clay.....	72'	
Till.....	10'	88'
Shale.....	9'	91'
Extra hard (FeCO ₃).....	3'	94'
Slate and shale with Lingula shale.....	12'	6"
Upper Coal (Upper Verne).....	2'	106'
Shale and Slate fossiliferous.....	9'	109'
Coal (Lower Verne).....	3'	118'
Fire-clay.....	3'	121'

The shells found here are largely the same as found at the Verne Mine. See p. 42.

Analysis No. A11 (B11) is from the Central Coal and Mining Co. on S. E. ¼ of the S. E. ¼ of Section 25, T. 14 N., R. 4 E., i. e., joins the Michigan Mine just described so that one escape shaft serves for both. As the analysis shows, this is of the same quality as the Michigan lower seam. It is here also the lower seam, 125 to 130 feet down, the section being somewhat as follows:

Clay.....	78'	
Till.....	31'	109'
Shale.....	3'	112'
Coal.....	2'	115'
Sandrock (?).....	11'	129'
Black shale.....	7'	133'
Bone coal.....	5"	133'
Coal.....	2'	136'
White sandy fire-clay.....	8"	11"

Analyses Nos. 7, 8, 9, 10 and 11 appear to be all from the same seam, the Lower Verne. As contrasted with the Saginaw seam, they are all high in ash, sulphur and volatile matter, but not coking coals, while the latter is low in ash, higher in moisture and not ordinarily, at least, coking. Analysis A12 is of the Upper Verne, in the Wenona Coal Mine, Bay County, and of better quality.



Plate IV. Upper and Lower Verne seams, Wenona Coal Mine.

(B). Analyses by H. J. Williams, referred to dry coal.

Table B refers to the same analyses as Table A, but the percentages are all referred to dry coal, thus eliminating that uncertain element, the moisture.

(C). Analyses for comparison by H. J. Williams.

Table C gives the results of analyses and tests on a number of standard coals by H. J. Williams for comparison. The proximate analyses refer to the coal as it came, but the ultimate analyses and heating power tests refer to dry coal. In the case of the Pocahontas coal, however, C4, there is very little moisture anyway. This is perhaps the best standard coal to use for comparison. For instance, it is included in the Lansing Water Works and in Willcox's tests, and Willcox's Calorimeter results agree with Williams' to within 2%. While, according to the calorimeter tests the Michigan coals run from 80 to 90% of the heating power of the Pocahontas (p. 105), practically they yield about 65% to 75% as much, so much heat escaping up chimney in the evaporated moisture of the coal, etc.

C1. "Big Muddy" coal from Carterville, Williamson Co., Ill.

C2. Pittsburg coal. Average of four analyses and tests. Compare the analysis of Pittsburg coal by Wuth and Stafford, with which F8 is compared.

C3. Clearfield, Pa.

C4. "Pocahontas" coal,—A West Virginia Coal.

C5. Nut coal. Mount Olive, Macoupin Co., Ill.

C6. Kinkad, a Hocking Valley coal, average of two analyses.

C7. Yorkville, lump and fine.

It will be noticed that the best semi-bituminous coals give from 14,500 to 15,000 B. T. U., while the good bituminous run from 13,000 to 14,000 B. T. U. for dry

coal. It follows by comparison that the heating power of the Saginaw seam is extra high when referred to dry coal, the weak point being the amount of hygroscopic moisture, for a bituminous coal.

(D). Analyses by C. H. Hilton.

Table D gives the results of analyses by C. H. Hilton, on material largely the same as Tables A and B. These analyses were performed as thesis work in the Michigan Agricultural College and published in the Michigan Miner for August, 1900.

Samples Nos. 1 to 4 were carefully taken from the material returned by H. J. Williams, with corresponding numbers. (D1 to D4=A1 to A4, respectively.) Analyses D5 to D8 correspond to A7 to A10.

D9 is from Grand Ledge, about the same material, perhaps not so carefully subdivided as E3,—a lump from Jenkins' drift on Coal Creek almost beneath the pits, the shales of which are exploited by the Grand Ledge Sewer Pipe Co., Frank A. Taber, secretary. Quite a full description of this region was given by Rominger.*

The sewer pipe works are close to the N. E. corner of Section 10, T. 4 N., R. 2 W., and the material is mainly derived from a shale from a pit about a quarter of a mile N., close to the Spiritualist camp grounds, at the summit of a bluff overlooking Grand River and a small tributary. The section here exposed is:

- 3 ft. stripping of till.
- 4 ft. shale, gray, with nodules.
- 1 ft. black shale verging into coal.
- 2 ft. white clay, so called fire-clay. The lower boundary of this white shale undulates so as to indicate that this is merely the shale below altered.
- 4 ft. blue clay, with large nodules of siderite and some zinc blende, and traces of ferns.
- 1 ft. darker shale, the floor of the shale quarry. Passing to the east into the Boyle's Mine Coal (horizon of Upper Verne?).
- 20 ft. light and dark thin bedded sandy shales and sandstones, slaking up on weathering.
- 1½ ft. coal, which is the coal analyzed (Lower Verne?). White sandstone.

The analyses of the darker and lighter shales are given in Part I. South of the works there is also a pit which lies much lower, in the valley of a stream and filled with water, and as the dip of the beds appears to be a little to the north, if anything, it is probably stratigraphically lower. The section is:

- 15 feet cross-bedded sandstone.
- 2 feet coal, with black shale and *Lingula mytiloides* just above.
- 3 feet white shale which I am told is the layer which is sometimes used. It is of different quality from the other, and the pit is generally filled with water. The shale here is much richer in ferns. (See p. 44.)

The coal workings consist of a series of little adits or drifts very irregularly driven in the bluffs facing the Grand River and mainly on the south side about ten to fifteen feet above the stream. Next to the northernmost with thickest coal is Pratt's coal mine, the adit being about 300 feet in, and the coal 28 to 30 inches thick. The next worker south is Chas. Hodge, then Wilkinson, then two other little openings, then the Jenkins old drift under the clay pits, and there is a new shaft on the Spiritualist Camp Meeting Grounds, put down by F. Boyle to the upper seam.

*Geological Survey of Michigan, Vol. VII, Part 1, p. 131.

D10 is from drillings of a thin seam of coal near Pinconning, S. E. ¼, Sec. 10, T. 17 N., R. 3 E., about 150 feet down, obtained through Mr. R. J. Mansfield.

D11 is from the Rifle River cannel coal, Sec. 3, T. 19 N., R. 4 E., about the same as G4 probably, though not identical samples. The coal is a cannel coal of very light specific weight, conchoidal fracture and little or no lamination, associated with Lingula shales, and showing no sulphur to the naked eye, so that the amount that the two analyses show is surprising. Upon exposure to air and moisture alternately, however, a white coating of iron sulphate soon forms. The section is quite fully described by Rominger,* as follows:

Disturbed material, drift	14	14
Hard calcareous sandrock	3	17
Black slate, with <i>Lingula mytiloides</i> and fish remains and cannel coal	10	27
There is also a lower seam (see analysis G5).		

Mr. Hilton's notes on his work are as follows:

"It will be noticed that the moisture and volatile combustible matter are uniformly lower in my determination than in the original analyses by Williams. Inasmuch as the amounts of these two factors had little bearing upon the present investigation, I made the determination of them together. To get at as to where the loss came in I made moisture determinations on three samples and found the loss of moisture accounted for the loss in the total moisture and volatile matter. Without going further, I took it for granted that the loss was thus accounted for in every case. The loss in moisture necessitates a higher proportion in the constituents, and I find accordingly larger percentages of total sulphur and of ash. The amount of sulphur in the ash is very small and is considered as sulphate in the coal. The amounts of volatile sulphur agree quite closely in the two sets of analyses.

"So far as the investigation has been carried the determination of iron has been the significant feature. I would call attention to the peculiar relation the content of iron bears to the content of sulphur. One varies as .does the other, and they stand in almost exactly the same relation to each other in every instance, viz., in combining proportion $56 \div 64.12$ to form iron pyrite (FeS_2).

CONCLUSION.

"As we stated in the introduction, the work has not been carried to its farthest analysis; and whatever conclusions are drawn must be stated as strongly indicated and not as absolute or positively demonstrated. But there is a strong probability, amounting almost to a certainty, that the sulphur is all accounted for correctly.

"First, A small amount of sulphur is non-volatile, being found as sulphate with calcium. Gypsum is found in perceptible amounts in coal deposits and the non- volatile sulphur is thus easily accounted for.

"Second, That the volatile sulphur is all combined with iron in the form of iron pyrite (FeS_2).

"This second conclusion is given weight by the fact that in all the samples analyzed, all the sulphur and nearly all the iron are accounted for by combining them as FeS_2 . It can easily be seen how, in one or two instances, these proportions would occur by accident and thus lead to erroneous conclusions. But it is extremely improbable that this accidental relation would occur in every case of samples of coal taken from eleven different mines in widely separated parts of the State. It seems just, therefore, to conclude that the volatile sulphur is rightly accounted for as FeS_2 . This is not saying that the iron and sulphur were originally deposited in these proportions. But that does not concern this investigation. The present condition in the coal is what I am after."

I called Mr. Hilton's attention to the well known fact that bi-carbonated waters containing gypsum will, in the presence of organic matter, yield H_2S freely. This would turn iron salts into sulphides.

*One or two interesting*Vol. III, part I, pp. 141 and 142.

"One or two interesting observations may be added. The coals are to all appearances perfectly dry, yet when they are subjected to a temperature of 100°C for one-half hour they lose 5 to 10% of their weight. The coal beds all being in valley regions and surrounded by higher grounds, have been for ages subjected to a strong hydrostatic pressure, which may account for the large content of hygroscopic moisture. Even after being handled about and kept in a comparatively dry place for some time, these coals yet yield as high as 8% moisture."

METHODS OF ANALYSIS.

"*Sulphur*.—The method used for determining sulphur was a modification of Eschka's method and has been already described. (P.60.)

"*Ash*.—Ash was determined by burning off in the muffle $\frac{1}{2}$ gr. of coal placed in a tared platinum dish, then weighing.

"*Iron*.—The ash from each determination for ash was thoroughly digested with strong hydrochloric acid, c. p. to dissolve out the iron. The HCl was then expelled with H_2SO_4 . The solution of ferric sulphate was then run through a reductor and immediately titrated against a previously standardized solution of KMnO_4 .

"*Moisture and Combustible Matter*.—I placed 1 gr. coal in tightly covered platinum crucible; heated over the Bunsen flame $3\frac{1}{2}$ minutes, then over the blast lamp for another $3\frac{1}{2}$ minutes. The loss is moisture and volatile matter. The determination of ash, moisture and volatile matter had little direct bearing upon the present subject. I made them to satisfy myself that the coal was practically of the same composition as it was in the original analyses. The samples had been handled considerably and it was thought there might be a loss of volatile matter accompanying a slight loss in moisture."

*Vol. III, part I, pp. 141 and 142.

The origin of the investigation was as follows:

In looking over some of the analyses of Michigan coals made for me, for instance A6, it was noticeable how low the ash was compared with the sulphur, so low indeed that if we estimated that all the iron which was combined with sulphur in pyrite (FeS_2) remained in the ash oxidized into ferric oxide there must be some sulphur which was not combined with the iron. So I suggested to Mr. Hilton for a thesis to work over some samples which I gave him to see if this were really so by determining how much iron was really present. It should be explained that between analysis and re-analysis they had been some weeks in bags and boxes before being separated and put into smaller jars. The samples originally taken, largely by myself, weighed twenty-five pounds or more, and were divided after returned from Boston and analysis by H. J. Williams into lots of about a pound. Thus, though the usual pains were taken in dividing, the samples had considerable chance to lose moisture and organic gases, and might vary a little in quality in the division. On the whole the re-analysis agrees with the original analysis remarkably well and

entitles both to a good degree of confidence. They indicate also the amount of variation which may be expected in analyses owing to variation in sampling and in the time between the taking of samples and their analysis.

It will be noticed that if Mr. Hilton had determined the moisture separately from the volatile matter throughout, he would have made complete proximate analyses, for by subtracting the amount of the ash and volatile matter from 100 we obtain the per cent of fixed carbon.

In regard to the relation of the ash and the iron, it may be noted that if all the iron were in the ash as Fe₂O₃, there would be 3-7ths more Fe₂O₃ in the ash than iron as given, and we see that in a number of cases the ash must have been practically all Fe₂O₃. But unless great and especial care is taken the iron will not be completely oxidized, but will appear in a metallic or magnetic shape. This, Mr. Geo. B. Willcox informs me, also has been his experience, and in such case of course the iron will not form so large a proportion of the ash.

The most important results of Mr. Hilton's investigation seem to me to be two. First, he has shown what a very small proportion of clay ash is in some of our Michigan coals. And in the second place, his results show that there is no sulphur in excess of that required to combine with the iron, but that they are almost in exact proportion, so that if we find the amount of iron in the coal and add one-seventh we shall find the amount of sulphur within a fraction of a per cent.

As it is far more easy to determine the amount of iron quickly and accurately than the amount of sulphur, this may be of practical value to the chemist. It suggests also that the sulphur was not there originally, but was precipitated by the iron, which was there first. The later statement is easy to receive and believe for bog iron deposits are common in connection with peat and muck deposits, and nodules of carbonate of iron are quite common in the coal measure shales. Now the waters of the coal measure shales are strongly bicarbonated, and beneath the coal measures are beds of gypsum, with which many of the coal measures are impregnated. It is a well known fact that if in bottling any carbonated waters containing gypsum any organic matter, such as a wisp of straw, should get in, H₂S is generated, a gas which would have power to convert the bog iron ore into iron sulphide.

It is also likely that iron sulphate has been reduced by the organic matter of the coal to iron sulphide. Finally, there seems to be a division into two groups of analyses; one low in sulphur, and another high, the percentages not being evenly distributed. This probably corresponds to the fact that the samples come from at least two distinct seams.

(E). *Analyses by A. N. Clark.*

The three analyses made by A. N. Clark, of the Michigan Agricultural College, in this table were also intended to throw some light on the same problem as Hilton's.

E1 is of the same sample as A1 and D1.

E2 is of the same coal as A6.

E3 is of the same coal as D9.

E1 and E2 would lead one to infer an excess of S over that required for sulphide of iron, but in view of the other analyses on the same samples, it appears likely that the results in sulphur are too high. This is probably due to the chemicals used in analysis not being free from sulphates. Mr. Hilton found the same difficulty in the beginning of his work,—the sodic carbonate supposed to be chemically pure, not proving such. The analyses otherwise agree quite well though made by different chemists, and the moral I would draw is the advisability of iron determinations as a check on the sulphur determinations.

(F). *Proximate Analyses.*

Table F includes a number of proximate analyses by various chemists. The accuracy of these we do not guarantee. As reported to me the sulphur is included in the summation to 100%, and in all probability to make room for it from the per cent of volatile combustible found as above described (p. [27]), one-half of the per cent of sulphur found is subtracted, and the other half from the fixed carbon. Therefore, to make them more comparable with analyses of Table A, I have added what the original figures for the volatile combustible and fixed carbon probably were.

F1. Sebewaing coal, probably from the mines of the Saginaw Bay Coal Co., at 80 to 90 feet depth, on section 18 of Sebewaing, T. 15 N., R. 9 E.

E. Speidel analyst, Twelfth Annual Report of Saginaw Board of Trade,—also our reports, Vol. V, Part II, p. 84, and Vol. VII, Part II, p. 218.

The following is a typical record from the neighborhood (Vol. VII, Pt. II, p. 150):

Sand.....	3'		
Clay.....	39'	42'	
Hardpan.....	3'	45'	
Sandrock.....	26'	4"	71' 4"
Coal, about.....		5"	71' 9"
Sandrock.....	8'	79'	9"
Slate.....	6"	80'	3"
Sandrock.....	7'	1"	87' 4"
Coal (analyzed).....	4'		91' 4"
Light shale.....		3"	91' 7"

While the following, being near by, shows the relation also to the underlying strata:

Pleistocene.....	{ Clay.....	51'	52'
	{ Sand and gravel.....	1'	54'
	{ Loose sandrock.....	2'	56'
	{ Hard rock.....	3'	58'
	{ Dark sandrock.....	18'	84'
Coal bearing series (Pottsville?).....	{ Coal, about.....	6"	74' 6"
	{ Sandrock.....	1'	76'
	{ Slate.....	6'	82'
	{ Coal (analyzed).....	3'	8"
	{ Bottom slate.....	1'	87'
Parma (?).....	{ Sandrock.....	13'	100'
	{ (Somewhat water bearing.)		
	{ Light slate or sand fire-clay.....	96'	196'
Grand Rapids.....	{ Hard dark rock (dolomite).....	24'	220'
	{ Slate.....	20'	240'
	{ Hard lime rock.....	8'	248'
Napoleon (Upper Marshall).....	{ Sandrock.....	55'	3'

In analysis this coal resembles the Lower Verne, and the occasional presence of another coal not far above it is significant.

This and F6 have the high volatile combustible and sulphur of the Verne seams though the volatile combustible is almost too high, and the ash must be almost wholly iron oxide from the iron sulphide. The samples may have been select lumps. Analyses A9 is probably of the same coal, but was taken by H. Ries unselected from the pile at the tipple.

A section of the coal seam at one point in the Sebewaing Coal Co.'s mine was:

Bone coal (burns but retains its bulk after burning, heavy)	0' 4"
Marcasite	0' 1"
Main coal	5' 0"

Mr. Chas. Holmes says: "Pyritic iron is distributed throughout the coal, reaching in quantity as high as 25% of the coal seam, and masses of it called boulders by the miners, in cubical crystals are found in the raw state. But while the amount of sulphur in the form of iron pyrite is undesirably high in this coal, which lessens its value by the formation of sulphide of iron and tenacious clinkers which have a tendency to destroy grate bars, still in furnaces where proper appliances have been used to overcome this objectionable feature, the coal has proved of high value for heating purposes."

F2. An old analysis of the Corunna coal from the Twelfth Annual Report, Saginaw Board of Trade. This is of the coal of the Corunna Coal Co., Tod Kincaid, manager, on Sec. 13, T. 7 N., R. 3 E., the same as F5 and G3. Inferior both in ash and sulphur to A4, which is near by at about the same depth.*

*I suspect that this is the Lower Verne coal from the analyses, and the fact given me by Mr. W. H. Hess that the roof is largely limestone, seems to be confirmatory.

F3. One of the first analyses of Saginaw coal, by A. W. H. Linders. It is cited with comparative boiler tests of Saginaw and Hocking Valley coal. Evidently the moisture had been driven off beforehand, and probably a little of the volatile combustible, and we cite it mainly to call attention to the fact that it is not an analysis of the natural coal.

F4. Analysis made by Heim Bros of Saginaw, for the Saginaw Clay Mfg Co., is supposed to be of the coal which was mined incidental to their shale work at Flushing. S. W. ¼ of Sec. 22, T. 8 N., R. 5 E. A view and description of their quarry is given in Part I. The general type of this analysis is that of the Saginaw seam,—high in moisture and fixed carbon and low in volatile combustible and sulphur. Borings on Sec. 15 and elsewhere in the neighborhood, however, show that there are at least 216 feet of coal measures here and indicate a higher position for it.

Compare analyses J7, 8 and 9, of drillings near by.

F5 is of the Corunna Coal Co. coal, an analysis furnished by T. Kincaid. Compare F2 and G3. The exact seam from which these analyses come is not well known.

F6 is of the Saginaw Bay Coal Co., coal at Sebewaing, by W. H. Coffron. Compare F1.

F7 is an analysis of Jackson cannel, quoted by A. Winchell 1861.

The large amount of volatile combustible is noteworthy and A5 and A6 are much like it, except that they have more water and less volatile combustible, and less sulphur. The former difference may be due to the analyst.

F8 is an analysis furnished by Wuth & Stafford in connection with the report cited above p. 64* on the availability of the Saginaw coal for a gas coal. Comparing this analysis with A1 to A3 the lower amount of moisture is noteworthy. This appears to be due to the imperfect separation of the moisture from the volatile combustible. The amount, of S is also abnormally low.

*Also Michigan Miner, May, 1901, p. 17.

(G). *Partial and proximate analyses of recent date.*

G1. By Prof. C. A. Davis, for O. W. Blodgett, of a coal from 89 to 110 feet down, supposed to be a pocket of drift coal, near Hunger.

G2. Average of nine analyses by students under F. S. Kedzie, of a piece of drift coal from Scotts, Kalamazoo county.

G3. Corunna Coal Co., average of 13 analyses made by students of Prof. F. S. Kedzie at the Agricultural College.

G4. Rifle River cannel coal, Analysts Dickman and MacKenzie, No. 8615. Through S. G. Higgins, Esq.

This is practically the same material of which D11 is an analysis, and the sulphur and ash check quite fairly. The material has a conchoidal fracture and a little lamination and occurs in association with Lingula shale. Near the river it is said to be but 17 feet down to this coal.

Beneath this cannel coal is said to be the seam of bituminous coal represented by G5.

I do not feel absolutely certain, but in all probability this analysis fairly represents the coal of the Eureka Coal Co., of which the following test by Geo. F. Sherwood of the Jackson Gas Works is given in the Saginaw Evening News of July 23, 1898:

Charge of coal	4,800 lbs.
Gas	15,600 cu. ft.
Burns freely with no clinkers, and makes a very hot fire.	

G5. Rifle River coal, lower seam, a single lump, by T. C. Phillips, at the Agricultural College, for E. C. Sovereign.*

Surface	103	103
Sandrock	7	110
Clay, some coal	2	112
Coal	5	117
Limestone	7	124
Coal	1½	125½

G6. Jackson coal, Rominger, agrees very well with A5 and A6 in showing that the coal at Jackson mines has over 40% of volatile combustible, and is a gas coal.

G7. Analysis of black shale from near Alpena, through W. H. Johnson, showing the real character of the stuff

which often starts coal excitements. Analysis of the ash will be found in Part I of this volume.

G8. Is an analysis of the five feet of coal shown in the following record from Sec. 13, Bingham Township, Clinton county, T. 7 N., R. 2 W., by Prof. F. S. Kedzie for M. H. Kniffin.

*This agrees quite fairly with older results (See Saginaw News July 19, 1898), less than .75 S., and 4¼% ash. A shaft is said to have gone down to this seam and found it 4½ feet thick and of good quality.

(H). Analyses by Bradley and Reed.

The analyses of this table were made by Mr. F. F. Bradley mainly; Nos. 1 to 6 at Alma, and with the assistance of Prof. C. A. Davis.

H1. Was reported as from the Verne mine, St. Charles. The analysis is distinctly that of a St. Charles coal, the Saginaw seam, and not one of the Verne coals. Compare A3.

H2. From the Standard mine, Saginaw. Compare with A2.

H3. From the Valley coal mine (Dutch Creek coal) near Bay City, as I suppose from the Monitor seam.

H4. From the New Hope mine, northwest of Jackson, should be compared with A5 and A6, which it resembles in proportion of volatile and fixed combustible.

H5. From the Trumbull mine, is of a shaft worked only a short time, northwest of the old Woodville mine, five miles from Jackson, Sec. 24, T. 2 S., R. 2 W., and is only a partial analysis.

H6. From the Wenona mine, Bay City, agrees pretty well with G2, but not so well with A7.

This mine has the following sections:

Clay.....	74'	
Sandrock.....	9'	83'
Shale (see Part I of this Vol.).....	37'	120'
Black shale, with <i>Lingula mytiloides</i> , which also occurs abundantly at the air shaft, is the base of this shale.		
Coal, lineations well marked with much dull charcoal. Parting of shale and sulphur streaks.....	3'	6" to 2 ft.
Coal (as sample) brighter, more pitchy in luster.....	3' to 2'	10"
Fire-clay, very siliceous clay shale, passing into a fine grained sandstone.....		
The coal is at a depth of 130 to 140 feet and the two coals are shown in Plates IV and VIII. Compare analyses A7 and A12.		
The lower bright coal I take to be the Lower Verne, while the upper dull coal may be the Upper Verne or Monitor coal.		

Going east 1,300 feet a 10-inch coal comes in on top of the upper seam. Where first seen it is 3 to 4 feet above, separated by a white sandy clay and gradually getting down to within 10 inches of it.

Compare this with the section of coal reported at Handy Bros.' Mine:

Coal, rusty with a few inches FeS ₂ at top.....	3'	6"
Parting, few inches.		
Coal, brighter, shinier, not as hard as upper coal, some FeS ₂ at bottom.....	1'	6"
Parting.....		4" to 11"
Coal.....	1'	

The bed rock is at 75 to 80 feet depth, the coal is at 110 to 120 feet or less, but there are 20 to 18 feet of roof shales.

H7 and H8. By F. F. Bradley and Reed of Chicago University, are from the same sample, taken from the Pere Marquette No. 1 shaft, as A1, B1, D1, E2. Analyses H7 and H8 are slightly better in most respects. The loss of moisture may be due to drying, possibly.

H9. By F. F. Bradley, is of the same sample as A9.

H10 and H11 are by Reed and F. F. Bradley, of the same sample as A10.

This suite of analyses do not agree satisfactorily with duplicates and suggest the question how much variation can be produced in reducing from the large sample taken to the small sample analyzed, and how much is due to difference in chemical manipulation.

The suite H runs steadily high in fixed carbon, yet if we compare A1 with A9 we find that H8 and H9 are similarly related, so that the relative behavior of the coals is the same.

(I). Recent Analyses.

Table I contains a number of recent and quite reliable proximate analyses, which are mainly accompanied by calorimetric tests.

I. This was an analysis by J. D. Pennock of a barrel of coal cut from the bottom to the top of the seam, at the mine of the Saginaw Coal Co. N. E. quarter of Section 31, Buena Vista township, T. 12 N., R. 5 E. It yielded 10,600 cu. ft. of gas, 110 lbs. of tar, 19.6 lbs. ammonia sulphate, and 54.50% of very good light coke, which analyzed:

Volatile matter	1.0
Fixed carbon	92.2
Ash	6.8
	100.0
Sulphur	.9

This was analyzed at the Solvay Co.'s works at Syracuse.

A record of the section at the mine is as follows:

Clay	54'
Sand and gravel, which turned out in the shaft to be a diagonal streak of a few inches	3'
Clay	37'
Sand	4'
Hardpan to bedrock	5'
Slate	1'
Coal, Lower Verne?.....	104'
Gray slate	18'
Slate	6'
Coal, Middle rider?.....	4'
Hard sandy clay	1'
Gray shale	5'
Strong black shale	12'
Coal, this is the coal mined (Saginaw seam).	3'
Fire-clay	18'
Sand rock	34'
Sandy shale	3'
Slate	16'

This is a little south and about 1,700 feet east of the north quarter post of Sec. 31, T. 12 N., R. 5 E.

This coal analyzes like the Pere Marquette, Somers, and other coals of the Saginaw seam and as such I take it. It rises rapidly to the Pere Marquette No. 1, and a little further east plays out against a big sandstone. The high per cent of moisture is characteristic, shown also in 13 and 14, and it is not superficially wet, but hygroscopic.

Analysis 12 was of a carload of slack with much sulphur and slate, which did not make a good coke—all came

out in a fine slate. It was impossible to drive off the last traces of gas. The coal yielded very little bituminous matter, a small amount of tar (25.10 lbs. per ton), 59.15% of a soft useless coke, of sulphate of ammonia, 17.40 lbs. per ton, of gas 10,000 cubic feet. Analyzed by J. D. Pennock, Feb. 17, 1899.

Analysis of coke:	
Moisture	3.2
Volatile matter	7.03
Fixed carbon	66.02
Ash	23.75
S.	100.00
	2.097

These analyses illustrate a general principle, that with the introduction of slate or bone coal represented by ash in the analysis, the fixed carbon drops faster than the volatile.

This analysis of slack is of course of no value as indicating the quality of the coal and there is more slate than usual in the marketed product. But it is very interesting, owing to the fact that less moisture appears than in the coal J1, or the coke. The idea suggests itself that the slate arid the sulphur can hold back the moisture which would otherwise be given off by the coal.

I3 and I4 are duplicate analyses of a sample taken by T. Pray, of Boston, in December, 1899, from a car of Saginaw coal, and analyzed at Cornell University. The calorimeter results are obtained by Mahler and Carpenter Calorimeters (p. 52).

I5 and I6 are derived from I3 and I4 by computation for dry coal, and I7 and I8 similarly for combustible.

These analyses show the largest amount of moisture of any quoted, though they are nearly equaled by some of Williams', e. g., A1 and A2.

Mr. Pray says, however, that the moisture is not surface moisture or snow, but an essential part of the coal. This burned up freely but soon lost its heat.

I9 is of drillings and I10 is of a lump coal from the Robert Gage Coal Co.'s shaft at St. Charles, on Section 10, T. 10 N., R. 3 E. I suppose the samples to be from the same seam as A3. The analyses were made at the M. A. C. laboratory, and the calorimeter tests made with the Parr Calorimeter. The same puzzling and important discrepancy in moisture to which we have already referred, appears.

I11 is of a lump from the top eight inches of "bone coal" from the same seam. It will be noticed that it has no more ash than A7, 10 and 11, H9 and J6, and that the ratio of fixed carbon to combustible is that of the main seam, I10.

"I12 is of fragments of an upper coal, one of the Verne coals encountered in sinking the shaft of the St. Charles Coal Co.

(J). *Supplementary analyses.*

Table J contains some coal analyses 1 to 6, by Lathbury and Spackman, which we owe to Mr. U. R. Loranger.

They are all from the neighborhood of Bay City and all probably from the Verne seams.

J3 is from the upper seam at the Michigan Coal and Mining Co.'s mine. Compare A10. It shows clearly how much better is the upper seam which they are now working, the upper Verne.

J4 is from the old Monitor mine, I take it, from the same seam.

The other samples are from undeveloped drillings, and the high percentage of ash is doubtless in part due to the admixture of slate.

J1 and J2, and J5 and J6 resemble in a general way A10 and A11, and are probably from the same seam. The ratio of fixed carbon to total combustible is lower than in the Saginaw seam.

J7, J8 and J9 are analyses by H. J. Williams of samples of drillings supposed to have come from near Flushing, which had been kept for quite a while, and are probably from two different seams.

(K). *Peat analyses by W. H. Allen.*

The analyses of this table are of peat, and were made by Prof. W. A. Allen of the Detroit College of Medicine for the Chelsea Compresso Peat Co., of Detroit and Chelsea, Mich. "No sulphur is reported. It is generally absent in peat. The percentage of moisture, which has not been separately determined, would probably vary from 10% to 25%.

Tables of analyses

TABLE A.—ANALYSES BY H. J. WILLIAMS.											
Number.....	1	2	3	4	5	6	7	8	9	10	11
Location.....	Free Marquette, No. 1.	Standard, Saginaw.	No. 1 Seam, St. Charles.	Oreoma.	New Hope, Jackson.	New Hope, Jackson.	Lower Verne, Bay Co.	Verne.	Selawating.	Michigan Lower Verne.	Central Lower Verne.
Sp. Gr.....	1.390	1.390	1.385	1.37	1.247	1.244	1.32	1.32	1.34	1.33	1.36
Moisture.....	10.15	10.67	7.79	7.58	5.58	5.98	8.71	5.82	6.09	5.01	4.52
Volatile Comb.....	32.14	32.39	34.74	35.70	40.73	40.59	35.45	39.79	39.54	39.45	41.18
Fixed Carbon.....	53.95	53.90	52.58	52.96	45.28	44.54	41.16	45.15	46.06	41.07	42.16
Ash.....	2.70	1.34	4.59	4.76	3.41	3.54	11.68	9.34	8.25	13.79	12.75
Sum.....	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total S.....	1.10	1.01	1.01	1.50	3.83	3.07	2.72	3.83	5.72	4.66	4.92
S. in ash.....	0.10	0.08	0.19	0.02	0.01	0.02	0.17	0.09	0.04	0.29	0.05
Volatile S.....	1.00	0.93	0.82	1.48	3.82	3.05	2.55	3.74	5.68	4.37	4.87
Iron % of volatile S.....	.87	0.82	0.79	1.39	3.46	3.06	3.23	3.27	4.97	5.57	6.01
Fe ₂ O ₃ % of volatile S.....	1.35	1.17	1.02	1.85	3.32	3.81	3.18	4.57	7.10	8.58	1.78
Clay (ash-Fe ₂ O ₃).....	1.51	0.77	3.97	1.91	0.11	0.97	8.50	4.57	1.16	5.74	4.17
Marcasite % of S.....	1.67	1.75	1.41	2.87	5.38	5.71	4.78	7.01	10.45	11.94	12.88
Corrected C.....	53.58	53.69	52.40	52.68	44.94	44.35	40.83	44.98	45.40	40.57	41.79
Hydrocarbon.....	32.64	33.12	34.33	34.96	45.32	45.07	37.18	37.92	36.70	36.44	40.16
C.....	71.11	71.67	71.37	72.88	73.55	72.42	66.87	68.33	68.07	68.29	69.37
H.....	4.74	4.90	4.48	4.81	5.77	5.73	4.00	5.09	5.35	4.62	4.78
N.....	1.40	1.40	1.40	1.40	1.50	1.50	1.03	1.25	1.40	1.30	1.19
O.....	8.84	8.49	9.35	8.04	8.37	8.53	5.28	6.62	5.15	6.90	6.30
Heating Power by Williams' Calorimeter in B. T. U.....	12,726	12,968	12,836	13,016	13,560	13,502	12,350	12,861	12,714	12,012	12,009
Calculated from ultimate analysis by Dulong formula	12,088	12,876	12,506	13,039	13,755	13,581	12,235	12,702	13,037	11,081	11,169
Heating Power in B. T. U. calculated from proximate analysis	12,783	12,810	12,798	13,035	13,580	13,479	11,700	12,520	12,767	11,905	12,406
"H" in B. T. U.*	147.47	148.50	148.25	148.64	150.88	151.76	156.37	156.67	156.29	157.39	158.50
* Computed from analysis by A. C. Lane. Phosphorus in No. 5, 0.018%; in No. 8, 0.017%; in No. 11, 0.014%.											

TABLE B.—ANALYSES OF MICHIGAN COALS BY H. J. WILLIAMS, REFERRED TO DRY COAL.										
Number.....	1	2	3	4	5	6	7	8	9	11
Volatile Comb.....	38.9	37.6	37.7	38.6	40.5	40.5	42.1	42.2	42.2	43.5
Fixed Carbon.....	60.0	60.2	57.0	57.3	48.0	47.5	45.1	47.9	49.0	43.8
Ash.....	3.07	2.17	5.30	4.07	3.55	3.02	12.79	8.91	7.79	14.42
Volatile S.....	1.11	1.04	0.89	1.60	2.90	3.24	2.80	3.97	6.04	6.71
C.....	79.14	80.20	77.40	78.98	77.00	76.96	72.16	72.55	72.49	65.37
H.....	5.28	5.45	4.86	5.39	6.11	6.09	5.27	5.31	5.61	4.87
N.....	1.86	1.87	1.82	1.87	1.89	1.89	1.10	1.33	1.50	1.26
O.....	9.84	9.51	10.03	8.79	8.86	9.06	5.78	7.02	5.49	7.17
Heating Power per unit dry coal calculated from result by Bomb Calorimeter.....	14,164	14,406	13,950	14,083	14,371	14,363	13,207	13,606	13,838	12,646
* Computed from analysis by A. C. Lane.										

TABLE C.—ANALYSES FOR COMPARISON BY H. J. WILLIAMS.

Number.....	1	2	3	4	5	6	7
Location.....	Big Muddy.	Pitts- burg.	Clear- field, Pa.	Poca- hontas.	Mt. Olive Nut.	Hoeking Valley.	York- ville.
Moisture.....	5.79	1.49	0.44	0.55	4.82	5.42	1.44
Volatile Comb.....	30.11	32.57	18.76	16.55	33.00	35.27	35.29
Fixed Carbon.....	55.79	57.87	73.15	76.94	49.50	52.79	53.06
Ash.....	8.31	8.07	7.65	5.96	13.68	6.52	10.21
(Lower figures, in dry coal.)	8.82*	8.19*	7.69*	5.99*	14.38*	6.90*	10.36*
Sum.....	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Total S.....	1.03	1.13	1.02	0.81	4.48	2.09	3.42
S. in ash.....	0.13	0.02	0.11	0.12	0.22	0.14	0.03
Volatile S.....	0.90	1.01	0.91	0.69	4.26	1.85	3.30
	0.96*				4.43	1.96	3.44
C.....*	71.81	75.57	80.17	82.85	63.21	74.63	72.28
H.....*	4.85	5.13	5.08	4.77	4.67	4.96	5.05
H— $\frac{1}{2}$ O.....*	3.41	4.04	4.49	4.22	3.12	3.71	4.19
N.....*	2.04	1.40	1.46	1.32	1.15	1.43	1.42
O.....*	11.52	8.70	4.69	4.38	12.16	10.02	6.85
146 C.....	10,490	11,020	11,700	12,100	9,240	10,890	10,630
620 (H — $\frac{1}{2}$ O).....	2,104	2,506	2,778	2,620	1,928	2,235	2,588
40 S.....	.096	.040	.096	.028	.255	.082	.138
Heating Power, $\frac{1}{2}$ Wet... Cal. Dulong†.....	12,120 12,885	13,680 13,867	14,490 14,572	14,780 14,880	11,100 11,674	12,420 13,151	13,310 13,404
	— 255	— 302	— 43	— 132	— 301	+ 116	78
Combustible.....	85.90	90.44	91.91	93.49	81.50	88.06	88.35

* Ultimate analyses and calorimetric results are referred to dry coals.
† By A. C. Lane.

TABLE D.—ANALYSES BY C. H. HILTON.

Number.....	1	2	3	4	5	6	7	8	9	10	11
Location.....	No. 1, PereMar- quette.	Standard.	No. 1, Somers.	Owosso Co.	Lower Verne.	Verne.	Sebe- waing.	Michigan Co.	Grand Ledge.	Pinecon- ning.	Rite River Cannel.
Ash.....	3.30	2.26	5.65	3.92	9.15	10.10	8.33	15.15	10.14	12.23	9.33
Total S.....	1.10	0.91	1.01	1.11	3.62	4.76	5.80	6.92	4.61	1.94	7.00
S. in ash.....	0.10	0.03	0.19	0.02	0.03	0.10	0.05	0.25	0.04	0.03	0.43
Volatile S*.....	1.00	0.88	0.82	1.00	3.59	4.66	5.75	6.67	4.57	1.91	6.57
S. from Fet.....	1.028	0.881	0.835	1.085	4.106	4.906	6.52	6.64	5.223	1.674	6.41
Iron.....	0.90	0.77	0.73	0.65	3.51	3.82	5.71	5.81	4.57	0.94	5.61
Volatile Matter.....	41.25	41.26	39.41	39.63	41.24	42.11	41.39	40.08	38.48	38.59	37.79
Heating Power.....	13,167										

* By subtraction.
† By computation as eight sevenths of the iron, compare p. 59.

TABLE E.—ANALYSES BY A. N. CLARK.

Number.....	1	2	3
Location.....	No. 1, PereMar- quette.	New Hope, Jackson.	Grand Ledge.
Moisture.....	10.40	5.20	7.00
Volatile Comb.....	32.40	45.65	39.10
Fixed Carbon.....	55.20	45.65	46.40
Ash.....	2.00	3.50	7.50
Sum.....	100.000	100.000	100.000
Total S.....	1.45	3.39	3.42
Fe ₂ O ₃ + Al ₂ O ₃	tr.	2.24	5.32

TABLE F.—PROXIMATE ANALYSES.

Number.....	1	2	3	4	5	6	7	8
Location.....	Sebe- waing.	Cor- unna.	Sagi- naw.	Flush- ing.	Cor- unna.	Sebe- waing.	Jack- son Can- nel.	No. 2, Pere Mar- quette.
Moisture.....	4.82	3.03	.....	10.425	3.968	4.46	2.00	1.98
Volatile Comb.....	44.58	38.78	31.39	29.70	39.476	47.92	49.00	43.49
Fixed Carbon.....	41.52	43.44	63.78	52.365	45.319	40.45	45.00	53.20
Ash.....	5.70	11.17	3.79	6.575	8.549	4.04	2.00	.97
Total S.....	3.38	3.57	1.04	.935	2.688	.305	2.00	.394
Sum.....	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000?
Total Combustible.....	89.48	85.79	95.21	83.00	87.483	91.42	96.00	97.084
Volatile ".....	46.27	40.57	31.91	30.17	40.820	49.44	50.00	43.69
Fixed ".....	43.27	45.23	64.30	52.835	46.663	41.97	46.00	53.40
Ratio of fixed to total comb..	.493	.527	.668	.636	.534	.458	.477	.55

TABLE G.—PARTIAL AND PROXIMATE ANALYSES.

Number.....	1	2	3	4	5	6	7	8
Location.....	Munger.	Scotts, Kala- mazoo Co.	Cor- unna.	Rifle River Cannel.	Rifle River, Lower.	Jack- son.	Alpena.	Kniffin, Clinton Co.
Moisture.....	{ 59.20 }	1.99	6.33	11.85	3.60	{ 17.96 }	{ 17.96 }	0.35
Volatile Comb.....	{ 40.03 }	40.03	35.46	35.80	44.00	{ 44.00 }	{ 44.00 }	32.92
Fixed Carbon.....	{ 32.22 }	44.89	45.45	41.10	55.40	{ 55.40 }	{ 55.40 }	28.76
Ash.....	{ 8.58 }	13.29	12.04	11.87	1.00	{ 1.00 }	{ 1.00 }	42.96
Sum.....	100.000	100.20	99.28	100.000	100.000	100.000	100.000	100.000
S*.....				5.84				7.68
Ratio of fixed carbon to total combustible.		.528	.561	.535	.57			

* In this and the following tables where no sulphur is reported, it was undetermined.

TABLE H.—ANALYSES BY BRADLEY* & REED.

Number.....	1	2	3	4	5	6	7	8	9	10	11
Location.....	St. Charles.	Standard.	Valley, Bay City.	New Hope, Jackson.	Trumbull, Jackson.	Wasson, Bay City.	PereMar- quette, Reed.	PereMar- quette, Bradley.	Sebe- waing.	Mich. Coal Mining Co., West Bay City.	Mich. Coal Mining Co., West Bay City.
Sp. Gr.....	1.216	1.19	.....	1.2315	1.28	1.202	.....	.....	.....	.....	.....
Moisture.....	7.15	5.54	1.7	5.53	3.94	2.06	6.33	5.963	1.492	1.48	1.890
Volatile Comb.....	37.56	32.67	35.25	44.61	39.80	41.4	33.90	34.682	36.409	36.18	34.117
Fixed Carbon.....	54.06	59.28	53.55	44.97	.....	51.89	57.88	57.375	59.284	54.17	56.693
Ash.....	.97	2.1	2.5	5	.....	4.05	1.89	1.998	11.704	8.17	7.800
Sum.....	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Total S.....	2.14	2.013	undet.	2.015	.....	2.044	.....	.....	.....	.....	.....
Ratio of fixed carbon to com- bustible.....	.59	.642	.613	.592	.....	.566	.631	.624	.581	.600	.59

* Some of these analyses prepared for a thesis for the degree of M. A. at Alma College.

TABLE I.—RECENT ANALYSES (MAINLY TESTED CALORIMETRICALLY).

Number.....	1	2	3	4	5	6	7	8	9	10	11	12
Location.....	Sagi- naw coal.	"Slack."	*Sagi- naw.	Sagi- naw.	Sagi- naw.	Sagi- naw.	Sagi- naw.	Sagi- naw.	Robt. Gage Coal Co., St. Charles No. 4.	Robt. Gage Coal Co., St. Charles Lump.	Hone coal.	St. Charles Coal Co., Upper coal.
Moisture.....	7.60	.825	12.39	15.51	.....	.....	.....	.....	1.72	2.37	8.08	4.84
Volatile Comb.....	37.865	38.765	30.47	30.38	34.78	34.61	35.27	35.21	33.74	36.18	30.74	40.13
Fixed Carbon.....	50.73	48.80	56.92	55.89	63.83	63.99	64.73	64.79	57.39	58.99	49.39	51.69
Ash.....	3.77	11.56	1.22	1.22	1.39	1.40	.....	.....	7.35	2.46	11.89	3.54
Sum.....	99.966	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Total S.....	.99	2.32	.....	.....	.....	.....	.....	.....	.....	.....	.885	2.22
Total combustible.....	88.655	87.565	86.39	86.27	86.61	86.00	100.	100.	91.03	95.17	80.03	91.62
Ratio of fixed carbon.....	.573	.568	.646	.647	.....	.....	.....	.....	.628	.619	.615	.598
Obs. Calorimet.....	12,581	.....	11,692	11,663	13,345	13,331	13,822	13,519	12,508	13,438	.....	.....
Calculated from analysis.....	.....	.....	12,600	.....	.....	.....	.....	.....	13,290	13,900	.....	.....

* Moisture part of the coal, not superficial, burned up rapidly, soon exhausted. Sample taken by T. Pray, Jr., Dec. 1899. Mahler and Carpenter calorimeters used.
† 27.068 to 27.736 grams of lead reduced per gram coal.
‡ 27.38 to 27.34 grams of lead reduced per gram coal.

TABLE J.—SUPPLEMENTARY ANALYSES.

Number.....	1	2	3	4	5	6	7	8	9
Location.....	Goetz No. 3.	Mas- sillon No. 1.	Michi- gan Mine.	Old Moni- tor.	G. Coal No. 1.	G. Coal No. 2.	Flush- ing No. 1.	Flush- ing No. 2.	Flush- ing No. 3.
Moisture.....	5.44	2.68	9.57	10.03	3.76	6.50	2.91	2.94	2.37
Volatile Comb.....	37.71	46.68	40.93	40.93	37.05	33.98	40.60	40.73	40.68
Fixed Carbon.....	48.43	40.93	46.13	49.94	50.10	40.60	54.35	54.06	50.82
Ash.....	8.42	9.71	4.35	4.67	9.09	18.92	2.14	2.27	6.13
Sum.....	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Total S.....	.59	3.08	.98	1.12	3.72	1.79	1.12	1.58	3.14
Total combustible.....	86.14	87.61	87.06	85.30	87.15	84.58	94.95	94.79	91.50
Ratio of fixed carbon to it.....	.557	.467	.530	.585	.575	.474	.573	.570	.556

In "Mining and Metallurgy for Oct. 1, 1901, p. 565, we find in regard to calorimetric tests that Dr. Langbein, of Meder Lossnitz, has constructed a new apparatus for that purpose. He publishes 150 complete chemical and calorimetric experiments of heating materials, and 153 purely calorimetric experiments, which he has carried out as a supplement to his experiments, in evaporation. The accompanying table is the result of his experiments.—British Foreign Office Reports, Annual Series, No 2,671.

	Calorimetric Units	
	From	To
Sawdust briquettes	3,400	4,100
Peat	2,700	4,800
Lignite	1,900	3,100
Briquettes	4,600	5,400
Bohemian brown coal.....	3,600	5,500
Coal from Silesia	5,900	7,500
" Saxony	5,400	7,200
" Saar district	5,800	7,700
" Westphalia	6,600	7,900
" Great Britain	6,000	7,800
Coal briquettes	6,100	7,700
Anthracite	7,600	8,100
Crude coke	3,500	4,000
Coal coke	5,600	7,400
Paraffin oil	9,800	9,840
Petroleum	10,300	10,330

These tests may be compared with Table II.

TABLE K.—PEAT ANALYSES BY W. H. ALLEN.

Number.....	1	2	3	4	5	6	7	8	9-9	10	11	12
Location.....	Michigan.	Michigan.	Michigan.	Michigan.	Michigan.	Michigan.	Canada.	Canada.	Canada.	Mixed.	Michigan.	Michigan.
Moisture and Volatile Comb.....	87.	89.25	82.5	69.75	56.5	63.25	51.	60.	49.	56.65	61.68	60.35
Fixed Carbon.....	36.	35.75	32.75	37.4	51.75	29.	35.	24.	19.	21.6	30.66	31.35
Ash.....	18.	15.	14.75	2.65	9.75	8.75	22.	15.	32.	12.75	6.02	8.50
Sum.....	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

§ 17. Conclusions.

Summing up the analytical tests and results of this chapter we may come to the following conclusions: There are but three seams, of the seven or eight existing, which have yet been worked enough to give us some idea of their character. They are all bituminous coals, rather high in moisture and inclined to be gas coals, and to pass into low grade cannel coal.

The uppermost of these three seams, the Upper Verne or Monitor seam, is the only one which appears to be at all gassy. It is a coking coal, duller than the next lower seam, and containing more charcoal, and a medium amount of sulphur. The roof is a Lingula shale. The ratio of fixed carbon in combustible runs up to .57.

The next seam, the Lower Verne, is generally not far - below, often near enough to be mined with it; it is also a coking coal, but is high in sulphur and ash. The roof is frequently fossiliferous and calcareous. The ratio of fixed carbon is lower, often less than .50.

The third seam, the Saginaw seam, is higher in moisture and fixed carbon than the previous seams, but contains much less ash and sulphur, in fact, very small quantities, but is not what is ordinarily classed as a coking coal. It is a good heating coal, but rather quick. The temperature of the chimney gases should be kept low, to avoid loss of heat in the evaporation of the moisture contained. For the Saginaw seam the best analyses give a ratio of fixed carbon to total combustible of 0.61, while in the Verne coals this ratio is usually near 0.50, but is more variable.

None of the coals as yet appear to be very well adapted for the burning of Portland cement, which is said to require a coal that is at the same time rich in volatile combustible and poor in sulphur. The cream of the Upper Verne coal, compare J1 and J3, meets most nearly these requirements.



Plate V. The flat Saginaw Valley. View south from dump of Saginaw Mine.

CHAPTER V. THE EROSION AND DISTURBANCE OF COAL.

§ 1. Recent channels.

After the formation of the coal beds, they have been cut into and partly carried away, not only by the now open channels of the present rivers, but also by channels which are now filled with unconsolidated materials, gravel, sand, till, etc., and by still earlier channels which are filled with rocks, usually sandstone.

We have then to discuss three kinds of channels, open channels, gravel channels or "washouts," and sandstone channels.

Open channels or valleys exposing the coal on their sides are neither numerous or deep, and this fact is one reason why the coal basin has been so tardy in development.*

Beginning on the east of Saginaw Bay and going around the basin with the hands of a clock, in describing such channels, we find that on Coats Creek, near Tuscola, coal is said to have been used many years ago from exposures in the bank, and sandstones occur in the bed of Cass River a short way above town. The Flint River near Flushing (Sec. 4 and Sec. 22), and the Shiawassee from above Corunna, at intervals down to Saginaw county, show exposures of coal measures. The Cedar and Grand Rivers show exposures at intervals from Williamston to six miles below Grand Ledge, and Grand River and the adjacent streams around Dimondale, Eaton Rapids, Chelsea and Jackson, expose some glimpses of the coal measures. There is a glimpse or two of coal measure sandstones at Ionia and as far northwest as Kent county, but thence there are no bedrock exposures until we get clear around to the Rifle

River in Arenac county at Omer and above. The center of the coal basin is heavily covered with drift.

Except in the comparatively small mines of Grand Ledge, the valleys are in no case so deep that coal exposed on the side of them can be effectively worked. It follows that there are no important self-draining coal mines. The States to the south, on the other hand, like Ohio, have deeper river valleys, and the coal was extensively exposed on the sides of the hill, where it could be worked cheaply and easily.

*R. R. Lansing. Exposition of the mineral coal of Michigan, pamphlet, Detroit, 1854; describing the earlier known exposures, especially those on Cedar River.

§ 2. Drift filled channels.

The States farther south have been somewhat covered with drift, but Michigan has been doubly plastered over; first rough coated with till and gravels washed directly from the great ice sheet which overspread it not so long ago from the northeast; then given a finishing coat up to nearly 200 feet above the present lake level by the deposits of the Great Lake system when the water was dammed up by the great ice sheet to the north, so that it flowed from a lake in the Saginaw valley across the peninsula to Lake Michigan, then ultimately to the Mississippi.

The smoothness of the resulting topography is well illustrated by the view from the top of the dump of the Saginaw coal mine, Plate V.

Before the period of the ice sheet, the land surface stood higher, and steep channels 100 to 150 feet deep and more were carved in coal measures. The cross-section of the Woodville mine, Fig. 4, reveals very clearly such a channel, which would have exposed the coal nicely before the glacial time.

Numerous other channels have been revealed by boring. One channel which skirts the east side of the Bayport limestone in Huron county is fully described in the report on that county.*

Leaving the county near its southwest corner it passes close to Unionville in Tuscola county, then flows west, crosses into Bay county, is well marked in Portsmouth and going south through Frankenlust township, probably enters Saginaw county in Kochville or Zilwaukee townships, thence goes southwest as far as Paines, receiving a tributary from South Saginaw. Then it passes west towards Alma, receiving a branch from Auburn and Midland, where the depth of drift varies from less than 200' to 300' or more.

The general course of some of the main channels is indicated by the bends of the rock contours of Plate I, but there must be many smaller tributaries not as yet located.

If this mantle of drift were stripped off it would be as easy to find the coal as in southern Ohio or Kentucky. As it is now, a great element of uncertainty in the development

and estimate of the amount of coal in a given tract is added. The closer the coal is found to the rock surface in preliminary boring, the more likely of course it is that one of these channels may be found cutting down to or through the coal. The Woodville section indicates, what is probably the fact, that they are often narrow and steep walled. Probably the general form of the rock surface is pretty flat and gently sloping to the middle of the basin, but engraved with steep-sided valleys.

It has been recently suggested in Mines and Minerals** that coal is likely to rise toward its outcrops, especially when underlain by fire-clay, and the cause suggested is the weathering and swelling of the beds when exposed to the weather.

This suggested principle holds true at Grand Ledge and a number of other points in other states which I have visited, and beside the reasons given for it in Mines and Minerals it may be due to the fact that erosion proceeds most rapidly along faults and anticlinals.

The figure of the section at the Woodville shaft, p. 33, indicates a similar relation of the coal to the old drift-filled channels, and similar relationships may be observed in the Pere Marquette No. 1 shaft and in Bay county. It seems, therefore, as though we might accept the following practical rule as of some value:

Toward an outcrop or washout, the coal is likely to rise.

*Part II of Vol. VII of these reports.

**By Charles Catlett, January, 1901; also Am. Inst. Min. Eng.

§ 3. Sandstone channels.

Besides the channels just mentioned we find others which have cut out the coal and are filled with compact sandstone.† These do not weaken the roof as do the former, but both classes make much trouble by letting in water. For instance, the mine of the St. Charles Coal Co. is so close-under a heavy sandstone, that it is quite wet.

These channels indicate that before the time of the ice sheet, in fact, probably soon after the coal was formed, stream channels were cut into the coal measures and then filled up again with sand- stone formed from the deposits. In Holcroft's plan of part of the Porter coal mine (p. 48) and in some other cases we can see clearly from the shape of the cross section that the sandstone channel really came down from above and cut out the coal.

Keyes* in one of his figures shows a sandstone cutting out the coal very much in the same shape as at the Porter mine. The erosion is also indicated at the Porter mine by the fragments of coal in the sandstone. Numerous records of borings seem to show where such sandstones appear in a series of records and replace the coal, but mere borings may be ambiguous. For when, as in the old East Saginaw well, we find 78 feet of sandstone replacing the shales and coal that occur in

the O'Donnell Spencer well and the Saginaw coal mine not three miles off, while at these latter points there is a well marked sandrock 34 feet thick or so just beneath the coals, it is not at all certain whether the East Saginaw sandstone is such a channel as we have been describing or whether the coal and shale series was not, as I am more inclined to think, laid down unconformably in a hollow in the sandstone, just as we find swamps between the sand ridges of the present lake shore. We have to search for reliable indications as to whether the sandstone which cuts out the coal connects with the beds above or below it. In the particular case of the Saginaw and Pere Marquette No. 1 mines, a careful study of numerous records convinces me that the coal rises up and laps upon and into the sandstone which occurs to the north and east for the first 50 feet or so below the surface, and that the coal was formed as a pocket or swamp in that formation against a sand ridge. Probable indications of real sandstone channels are also frequent, as when Mr. Liken near Sebewaing, put down a well for water,†† and found three feet of coal 36 feet from a previous boring which at the same level was in the midst of over 20 feet of sandstone.

I think that where the want is produced by a sandstone cutting down from above it is likely to be less extensive than otherwise.

The rock channels besides being described by Keyes as cited, are well described by Stevenson in Pennsylvania, who is really pioneer in detailed description of bituminous coal sections.

†Keyes, Iowa, 1894, pp. 181-186.

*Loc. cit. Fig. 20.

††Vol. VII of these reports, Part II, p. 149.

§ 4. Faults or displacements.

Coal beds are liable to be disturbed or interrupted and deteriorated, e. g., by the following features:

(a) Faults, i. e., displacements which are almost always "normal," i. e., the surfaces of displacement slope toward the side on which the coal dropped, so that the coal may be imagined to have slid down. See the figure of the fault at Sebewaing (Fig. 3, p. [15]). This is likely to be the side of the thicker coal. The fault lines are frequently occupied by—

(b) Clay seams or veins (perhaps occupying the fissures made by the faults) which traverse the coal.

(c) "Sulphur partings," that is, veins or seams charged with sulphide of iron.

(d) "Spar seams," that is, veins or seams filled with some white material, generally either calcite, which effervesces in vinegar, or gypsum, which does not.

There are other phenomena which are sometimes called faults, for almost anything which prevents the miner from finding the coal where he expects it, he is liable to consider and call a fault, including not only

displacements such as we have mentioned, but rolls, horsebacks, sandstone bars and channels.

In such a broad sense it would be better to use a term like "want" or "trouble." The geologist, however, limits the use of the term faults, and applies it only to those cracks in the earth's surface by which the coal has been displaced and the beds above and below as well. In the Jackson coal mines we have such displacements and there is one well developed in the mine of the Sebewaing Coal Co. (Fig. 3). Here the coal rises more sharply as we approach the fault, and this is often the case. The motion and slipping along the fault place has polished off smoothly shining surfaces in the coal and slates, sometimes as bright as jet, which are called slickensides.

Along the fault line, which has a dip of about 65°, there are open holes, apparently water channels, which appear to have been dissolved out by underground waters working along the cracks and dissolving the pyrite.

The actual throw at the fault is but two feet or so. The Iowa faults are described by Keyes as follows: Seldom with more than a few feet throw, the majority normal, with a grade 15° to 45° from vertical, the two faces of the rubbed fracture very dense and highly polished. Frequently there are a number of faults parallel to each other. In some instances, in passing from a hard to a soft medium the line of fracture is bent away from a normal to the contact plane like a ray of light, passing out of water. Reversed or thrust faults, Gresley's* "Slack" or "soot" veins are little known in Michigan, but there are said to be a few around Jackson.

*Bull. Geol. Soc. Am., 1898, Vol. IX, p. 47.

§ 5. Veins.

(a) Clay-filled veins, "clay seams," "mud seams." The phenomena known by above names have been quite fully described and figured by W. S. Gresley,† and but little is known of them in Michigan, so that we need not dwell on them here. In the majority of cases, perhaps, they are fillings of shrinkage cracks, and one may be described in a general way as a more or less vertical, crooked, tortuous, often branching, ragged-sided wall or dike intersecting a seam of coal, composed of compact indurated clayey materials or a mixed debris of rocks forming a breccia or conglomerate mass, varying in width from a mere streak or film of clay to as much as 15 feet, but averaging about 10 inches. It may have any direction, may extend a few yards only or run a mile or more before being lost to sight. It may branch and even reunite vertically and horizontally, and the adjacent coal may be toughened, twisted, and spoiled or displaced. In this latter case the clay vein probably occupies the fissure of a fault. It "may form part of a network of veins and may extend indefinitely above and below the coals." Though Gresley says that the direction of the clay veins is irrespective of other structural features of the coal, some of his figures (6, 7, and 16) suggest that those

which he figures are divided into two systems, which, though more or less irregular, are at an angle to each other which is bisected by the cleat of the coal, as torsion cracks of a substance twisted under pressure are bisected by the direction of pressure. These figures would then indicate that in such cases the cracks were opened by a twisting of the coal seams, while under such a pressure that clay was forced into the cracks, and a "cleat" produced.

Other figures given by Gresley indicate that in the cases they represent the clay seams figured were due to the shrinkage of the coal, under a pressure that forced the clay into the cracks as they opened.

†Bull. Geol. Soc. Am., 1898, Vol. IX, pp. 35-38.

(b) Spar veins are more likely to be smooth coated, following the cleat or joint planes of the coal. They are generally white, in strong contrast to the dark coal, and are usually not over a fraction of an inch thick.

(c) "Sulphur partings."

These are pyritic streaks, i. e., streaks of sulphide of iron, either in the shape of pyrite or the similar but more easily decomposable mineral marcasite. When they cross the coal nearly vertically they are probably veins following faults, but they also occur in streaks parallel to the bedding. While in some cases they correspond to the faults, in other cases no disturbance is noted. Holcroft's plans of the Jackson coal district show them abundantly.

The "sulphur" was once sold for 5 cents more per ton than the coal to an acid and fertilizer factory at Jackson, and one of the open fields is the economic utilization of the waste pyrite of the Lower Verne seam around Bay City.

In connection with the waste bitterns for potash, and the slaughter-house refuse for phosphorus, I imagine a successful fertilizer business could be built up.

It might also be used for cheap large scale disinfection.

§ 6. Horsebacks or bars.

Keyes* gives a figure of a horseback in the sense of a ridge rising from beneath the coal, that is from the footwall, which is remarkably sharp. He defines a "roll" as a place where the roof occupies a portion of the seam. It may be a mere indentation or nearly replace it, i. e., be a "pinch," and may occur in connection with a clay seam or fracture, which fact he also mentions.†

On the other hand, Stevenson‡ calls "horsebacks" what Keyes calls "rolls" and we have called "channels," coming down from the roof and cutting out a greater or less thickness of clay, while rolls lie defined as swells of the under clay. It will be observed that Keyes and Stevenson are diametrically opposites in their definition. They may both conform to local usage, but miners are not scientifically precise in their use of language and steer clear of barren spots, no matter by what names

they are called, so that in very many cases we are not certain of the nature of the intercepting beds. For instance, between the Standard mine on Section 6, Bridgeport township, south of Saginaw, and the Pere Marquette No. 1 and Saginaw mines coal basin, there is an area where the coal seam of those mines does not appear, being said to be cut out by a big sandstone, which is said to come in from the roof. It is really not certain, however, whether it is a channel or a bar; my own impression is that it is a bar, as there is a rapid rise to the south approaching it in the mine, running up to 5° or 6°.

It seems certainly more natural to speak of a rising up of the foot-wall as a horseback. When we can be certain which we have, it will be better to avoid ambiguity and speak of channels and bars, and otherwise to speak generally of "wants," a miner's term for places where the coal is wanting.

We may picture the formation of bars as follows: Suppose the shore of Saginaw Bay to be depressed and buried, and covered with later deposits. The swamps behind the sand ridges would in course of time become thin coal seams, and the sand dune ridges and oak islands would become sandstone bars and horsebacks.

Other bars might be due to uneven pressure and settling with faulting. If clearly made out we should call them fault blocks rather than bars.

*Iowa, 1894, p. 206.

†Iowa, 1894, pp. 189-266.

‡Penn., KKK, p. 295.

CHAPTER VI. THE DEVELOPMENT OF COAL.

§ 1. Peculiarities of occurrence as affecting development.

There are some peculiarities in the occurrence of coal in Lower Michigan which have retarded and will affect its future development.

As we have said, practically all the coal lies below water level, and mainly in artesian well country. Ample provision must therefore be made for economical pumping. Care must be taken to steer clear of porous beds and fissures, and artesian wells. The water from an artesian well whose casing burst was a considerable annoyance to the Sebewaing Coal Company. The water has flooded their mine since this report was first written. For the same reasons slopes or inclines leading down to the coal will probably not be advantageous, as the water will find its way in too much, and though they have been tried at Jackson, Elk, Williamston and Corunna, have not been successful. The amount of water to be handled has* been a great source of annoyance and failure, and it is important that the shafts for pumping should be put down in the lowest parts of the coal, so that the water

may run to the pumps. This requires careful preliminary testing, and the test holes should be plugged, lest they aid the circulation of water and make necessary more pumping.

The presence of numerous deep drift channels also makes the work of development uncertain. They are to be carefully avoided, since near them the roof is likely to be treacherous, and often the weakness of the roof prevents success. Thus the true value and best method of working an area of coal lands cannot be determined without an expensive series of preliminary borings.

The strata are quite a little disturbed and uneven, and though Lawton† is somewhat within the truth in saying that there is but one workable seam, "never over four feet deep," and averaging 2½ to 3, it is true that the beds are prevailingly thin.

On the other hand, fire-damp and coal dust explosions are almost unknown, and other noxious gases are not troublesome.

*Lawton, 1881, p. 24.

†Lawton, 1895, p. 173, and other places.

§ 2. Principles to guide explorations.

Summing the results of our inquiry, we may lay down with some caution the following practical principles, which should be compared with those laid down by Winchell:*

(1). A good place to begin preliminary explorations is a belt a few miles (five to fifteen) within the limits of the coal basin as marked on Plate I. Nearer the center some of the coal beds are liable to have run out (though there may be higher later formed ones of which we have no knowledge), and the drift and depth to coal is greater. Nearer the margin the coal is more likely to be cut out by some channel and the base of the coal series is soon reached, but—

(2). A coal bed once located, though not thick enough to work, may often thicken, especially in that direction parallel to the margin of the basin, in which it grows deeper, so that it may be followed by borings to where it will be worth working.

(3). Generally speaking, the coal will rise toward the margin, except for minor undulations. But shafts should not be located until the property is so proved up by borings that they may be located at the lowest point of the coal.

(4). Hitherto almost all the work has been done on the southeast side of the basin. A line from Sebewaing to Jackson, and one from the Wolverine Mine, near Bay City, toward Grand Ledge, would be very nearly parallel, and would include practically every mine in the state that has produced coal in commercial quantity. The little that has been done at Standish, and around the Rifle River, at Hubbard, Pinconning and Rhodes, has not been more than sufficient to show that coal exists there. Montcalm

county and the valley of the upper Muskegon are promising regions entirely undeveloped, for the rumors of coal found there seem to refer entirely to coal in the drift.

(5). Over most of the coal basin there is an extra heavy coating of unconsolidated materials (drift), and probably the coal measures have suffered heavy erosion. Hence exploring for coal alone will be too expensive to pay, until we have more definite knowledge than at present, so that it is very important that careful records be kept and preserved of borings for all other purposes, e. g., artesian water and bromiferous brines, which are likely to occur in this region.

This is especially true of the northwest region, where the surface drift is apparently over 300 feet deep.

*1861 report, p. 157.

§ 3. Methods of testing and developing.

We pass next to consider methods of explorations and testing. The one that might be thought of first, viz., sinking a shaft, is the last to be used, and in fact need not often be resorted to, until it is time to begin mining. The first method suggested is that of digging wells or test pits, as they are called in the iron country. As a general thing, however, any coal reached by shallow pits will not be conveniently workable—the coal will dip away from the shaft and be wet, and very likely have a poor roof.

The methods of exploring suited to the iron or copper country, or to putting down wells in unconsolidated deposits, are of no use save in exceptional circumstances. When previous explorations have made it probable that only soft shales in the way of rock overlie the coal, and when the overlying drift is not very thick and very bouldery, dug wells may be used. Bored wells (in clay) and driven wells (in sand) will find their main utility in tracing out cheaply the form of the surface of the bed rock where there is danger of gravel channels. When there is a probability of encountering an embarrassing quicksand it may often be a good thing to use the scouring process (by which a strong stream of water washes out the sand ahead of the casing as it is tapped down) until the casing is extended to bed rock; after which it will be easy to begin drilling.

The main reliance is upon drilled wells, and we may divide drills into two classes, churn drills, with an up and down motion (percussion drills), and rotary drills.

Churn Drills.—The churn drills are the kind commonly used by drillers in putting down artesian wells for farmers, saline wells, etc., and are usually the first thing at hand and in many cases the cheapest. Most incidental explorations will have been done with them, and the records are well worth keeping. Their chief disadvantage is that the drillings from a churn drill (which is worked by dropping the tools down frequently upon the rock while they are slowly rotated) come up as fine as powder or meal, with the parts from different layers

more or less mixed, so that it is difficult to determine the exact qualities of the rock, and exceedingly easy to confound with the coal more or less of the black shale roof that almost invariably comes above it. By reaming out a small hole to somewhat larger size, somewhat coarser samples may be obtained, and I am informed by those experienced, that they can recognize with their hand on the cable the peculiar crunch of the coal under the drill, owing to its greater brittleness, when it is struck, and by then turning the drill exactly 90° between each stroke, and "quartering" the coal, they can get larger fragments. So that if they also hoist and bale out with the sand pump at every few inches on passing coal, or use so called "jetting" tools which wash out the meal continuously, they can get a very fair idea of the coal. But there is a great weight of responsibility both on the skill and on the integrity of the driller.

There are two styles of churn drill, according as a cable is used to lower the tools or a series of poles. The former gives rather cleaner samples, for the poles tend to knock off more pieces of the rock along the way down. But the poles have the great advantage that on nearing the coal, they can be changed from a churn drill into a rotary drill.

The cost of putting down a single two-inch hole for a farmer's well two hundred feet or so, around Saginaw, has got down to 50 cents a foot or so of late. It used to be considerably more, and the real cost varies greatly according to the particular difficulties encountered. A driller must allow a good margin for contracts on the first few holes in a new district. Limestone or pyrite take very much more time than sandstone or shale, and accidents of one sort or another seem to take half the time of drilling a well. The cost to a company owning their own machine and putting in many holes where the formation is well known, I understand may be not over 25 cents to 35 cents a foot.

Rotary Drills.—The simplest form of rotary drill is probably the crown drill—a length of gas pipe, with notches like saw teeth filed in the cutting end, or a tempered steel drill of the same shape. In sandstone explorations nice cores have been taken out 3 to 4 inches in diameter by a chilled steel drill, at a lower cost for fifty feet or so than the churn drill. In this form ordinary gas pipe is rotated, while beneath it have been dropped angular fragments of an especially hardened steel or "adamant." Practically it is a method of grinding one's way down. Mr. Etzold's explorations for the Michigan Coal and Mining Co. were largely by this method.

As coal is very brittle large cores must be taken if it is expected to get them up whole.

The diamond drill has the edge of the round bit armed with black diamonds, known as carbons or bort, set alternately on the inner and outer side. These drills are at present very expensive (\$1,000 to \$2,000). It has been but little used, the 907 foot hole at Corunna* being the chief instance. Mr. N. P. Bradley also put down a

hole near Bay City, described p. [69]. The diamond drill is most effective in a hard and uniform rock, like hard pyritic sandstone, and is especially to be recommended for very hard rock, but is not to be recommended when the rock is soft and sticky, or especially when of very irregular hardness, breaking away in angular bits that jam, like some conglomerates and cherty limestones. Cores 1½ inch in diameter cost somewhere about \$1.00 a foot. In sandstone and shale the cost has been as low as 44 cents a foot, and progress as rapid as 30 feet a day.† The relatively least expensive depth is, when the diamond drill is used, about 600 feet.

In all rotary drills the drill is forced into and against the rock, and the hole is more likely to be crooked than where the drill is dropped.

It is obvious that no one form of drill that we have mentioned has all the advantages under all circumstances, and the subject is so far out of the line of our main purpose that the remarks alone serve merely to remind one of the expense and desirability of exploration,‡ the advantage which a man educated to the business has in choosing the method best adapted to the circumstances, and finally to suggest to driller, land owner or explorer a wider range of investigation and choice of that which will serve his need than might otherwise occur to him.

If it is merely a question of following the coal into the valley or "swamp," or of determining! the amount of roof and presence of channels, a churn drill in an experienced and reliable hand should suffice. If the quality of the coal or adjacent beds is in question, a crown drill or a drill that will give a three or four inch core at least should be employed, and I should recommend taking at least one core before sinking a shaft.

*Vol V, of these reports, Plate XII; also Lawton, 1885, p. 176.

†See Mines and Minerals, Jan., 1900, also Vol. VI, Part I, of these reports.

‡See The Michigan Miner, No. 2, Jan. 1899, p. 10.

Sinking Shafts.—So far as concerns sinking shafts, we must refer to any treatise on mining, as it is too large a subject to try to summarize. We need only add that in the district under consideration workmen have often encountered dangerous flows of water in putting down wells, so that preparations must be made to fight water and timber closely. In putting down shafts against water it has often been found advantageous to put down two shafts together not far apart, running first one and then the other ahead a few feet, and pumping vigorously in the other one. There is no loss in this in coal mining, for two shafts are needed for ventilation and safety anyway.

§ 4. Incidental development and information.

It is obvious from what has been said that the heavy expense of the necessary preliminary explorations prevents the development of many coal bodies, which once located could be worked at a profit, and many of

the borings for water and brine would, if properly watched and recorded, give valuable information as to the presence of coal. But the following conversation is typical:

"Say, don't you remember that you brought in some coal to me when you put down that last salt well for me some years ago?"

"Yes, and you said, 'What are you giving us?' and suggested that I had dropped it down."

"Well, do you remember how far down it was and how thick?"

"No, I can't say now, but my machine is right near here, and we can run her down and see very easy any time you like."

Some of the better well drillers keep a careful record of all their holes for whatever purpose, but no record is as good as a set of samples, for there may arise some entirely unforeseen questions as to a particular quality of a fire-clay, of the presence of clays, iron ore, or zinc ore, which no one thinks of now (any more than the saw mill owner, hard pressed to get rid of his slabs, used to care for a small bed of steam coal), but which may later be of practical value. If records, and especially if accurate tubes of samples such as adorns the corridor of the Alma Sanitarium, had been kept of all the wells which have been put down, it would be possible to save thousands of dollars in fruitless explorations, by guiding explorations in future, so that the right spots for shafts may be sooner found. Not only this, but there would be a fund of information concerning many other raw materials destined to become of economic value.

Beside borings there are other sources of information so indirect and technical in their character as to belong to the professional geologists. The presence of coal in surface deposits, if in the till, indicates coal to the north-northeast and not directly beneath, but if abundant and coarse, not far off, if in river sands in the rock or till upstream. Again, the well waters are often more highly sulphated in the Coal Measures.

Role of the Geological Survey.—Now the part of the State Survey is to put together, and aid and guide the collection and preservation of this information. Two and two of knowledge together often make more than four. A well that shows no coal may show some bed recognizable in other wells that do contain coal, by which we may infer that it has not gone far enough and the coal is still beneath, or perhaps that it is cut out by a channel, and may so guide us in farther search. If one studies the reports of great mining States like Pennsylvania, where the publications of the Geological Survey run into the hundred, he will find that a vast amount of the data is furnished by private exploration. The natural exposures in our coal basin are very much fewer, and it is to be presumed that my predecessors have largely made what can be made from them. And yet there is a great deal more to be known about the geology and natural resources of the Saginaw Valley,

and each year many wells are sunk which would throw light. The State Survey cannot undertake the work of the private explorer, in finding out the value of the land of a particular private individual. But the State may play the part of a vast co-operative society, and if it can guide him in putting in his work and money to best advantage, and in return receive information which is of no exclusive advantage to himself, possibly of no immediate practical value to anybody, which will in due time enable the State Survey to help some later investigator as it has helped him, an important function as far as the economic development of the State is concerned will have been accomplished. Its relations, to educational and purely scientific interests we do not touch,

§ 5. Promoter and land owner.

We are now prepared to better understand the use of the "man who wants an option," whom we have agreed to call for short the promoter. The coal under a piece of land may not pay to work by itself. Prof. Pumpelly has shown very clearly that large coal mines mine more economically, and pay a larger percentage of the selling price of their coal to the workmen. Land should then be gathered into aggregates for working, large enough to give a chance for the most economical mining. Moreover, before any mining is done there must be considerable exploratory work, to determine how best to mine the coal, where the lowest spots best for sinking shafts may be, and where are the channels cutting out the coal which should be avoided. But no man can be expected to go to the expense of exploring and drilling for coal, unless assured that some of the increased value which will come to all the land around a successful exploration will be to his benefit. In all this there is no question of over-reaching anyone. It is a plain business proposition. This gathering of the coal rights of land into developable tracts is the work of the promoter.

How should such offers be met?

In the first place unitedly. Owners of adjoining tracts should agree on options or terms to the same party, or if they choose should co-operate in a company for developing their lands themselves. If certain owners stand off and refuse to unite with their neighbors, the very best places for shafts, and the most economical mining, may be impracticable. Suppose for instance a want or channel runs diagonally through a quarter section so as to isolate in one corner a few acres of good thick coal. That coal might be profitably developed and taken out in connection with the coal on the adjacent farm, but if that is leased to a different party or the neighbor refuses to lease, it becomes practically worthless, except to one man who can later name his own price.*

On the other hand, if a few big companies get hold of all the land except a few small pieces not worth working separately, they can force the remaining owners to take about what they choose to offer. This has been very notably the case in the Mesabi iron range in Minnesota.

A few companies control the situation. This is an age of combination, and combined action will prove most successful. The owner who, not having land enough for independent working, refuses to unite in joint negotiation with his neighbors, may injure them, but is far more likely to damage himself.

Secondly, the promoter should be met fairly. He is about to risk some money in exploring, and if one wishes to aid in the progress of the country, and give men of moderate means a chance to have a share in it, one should not demand too much money in advance for coal rights, provided the terms in case the explorations are satisfactory give a fair and customary share of the profit to the land owner, either in the shape of royalty on the output, or a lump sum for the sale of the coal rights. But what is too much? And what is a fair share? These are difficult questions to answer, for much depends on local conditions, but we shall try to throw some light on them in the remaining sections.

It is well to remember that a considerable sum of money must be spent in preliminary testing, and, if that proves promising, in preliminary equipment, before any returns are realized, and it is obvious that in making, for example, present cash payments for coal rights, a large margin of prospective profit must be allowed, to tempt a man to incur cash outlay. Without much doubt the most satisfactory plan is to have the land owner assume part of the risk and have his profits depend upon the success of the venture, by making the payment to him come (outside a small cash payment to bind the bargain and as a guarantee of genuine work), in the shape of royalties, i. e., a fixed sum per ton for each ton of coal mined. This has been the almost universal rule in Michigan, the royalties running from 6 to 15 cents per ton. The more certain the amount and the greater the thickness of the coal, the higher the royalty that may fairly be demanded. Probably 8 cents is the most common figure.

*Near St. Charles there is some coal on the N. E. corner of the N. W. quarter of Sec. 17, which could best be handled through the Somers No. 2 shaft, and perhaps is only worth handling through it.

§ 6. Labor value of coal.

The value of coal as of everything else depends on two factors, the cost of production, and the scarcity of the material. It is the last value only which the land owner possesses, and with which we wish to deal, and yet we cannot easily separate the two sources of value. The scarcity is almost invariably in any article, certainly so in coal, not absolute, but the scarcity of sources of supply that will yield the coal so that it can be laid down in a given market, say Bay City, at a given cost.

To make the matter more practical, the scarcity value of Michigan coal is the difference between the cost of the production, and the cost (including labor in the mines and transportation, etc.), of delivering coal from States where there is more than they know what to do with, like Ohio and Pennsylvania, of the same grade in the same

market. This is with the proviso that, as at present, there is not enough of the local coal produced to supply the demand for soft coal, and some imported coal is needed to make up the difference. If and when the mines in the neighborhood of Saginaw can supply more coal than the local market can take up, the price will fall, until one of two things will happen. Either the mines or parts of mines producing at greatest expense (on account of narrowness of seam, amount of water to pump, insufficient transportation facilities, poor roof, etc.), will shut down, as the price has fallen where they can make no profit, or the surplus coal will be sent away and replace Ohio coal elsewhere until the market is made large enough to take the supply. The farther it goes south, the greater will be the freight charges, and the less the amount which the mine will receive. For instance, at Lansing Hocking Valley and Saginaw Valley are in close competition, at about \$2.05 per ton. The freight charges on the former are \$1.40 per ton, on the latter \$0.70 per ton. The mine in one case gets 65 cents, in the other \$1.35 per ton, and if it costs the same to mine the scarcity value would be 70 cents a ton. But as I have in the next section remarked, it costs nearly 1.30 a ton to mine coal in Michigan, leaving only five cents margin of advantage of position to the Michigan coal. Until the freight rates are revised, therefore, Michigan coal cannot go much farther south, unless the average cost of mining decreases.

Before the independent mines producing coal more expensively are shut down, the laborers, unless they are effectively organized, will be ground down to the last notch, and the easiest mined coal gouged out. Finally the mines which are unwisely planned, or worked with insufficient capital, or on an uneconomically small scale, which Prof. Pumpelly has shown is generally true of the small mines, will have to shut down. In short, first the laborers and then the small operators, or vice versa, depending on which is best organized, will suffer. This is the process known in the financial columns of the papers as "getting the business into strong hands." In other words the control of the production becomes vested in a few men, who directly through a trust or indirectly by a general understanding, determine how much coal can be mined each year to best advantage, and can afford, as they work on a large scale, to keep reserves of coal until later and shut down the mines they can least profitably work.

It is plain that the first alternative suggested, that of crowding the weaker mines to the wall, is not pleasant. It produces the misery, the constant strife between workmen who must fight for a living wage, and operators who *must* grind if they keep in business, with frequent strikes and the bloodshed and misery that may attend them. Yet this was the normal or rather the regular way of keeping down the production in the States to the south of us, where there is vastly more coal than the country can consume, and here we find the coal mine operators of one district subscribing to the strike funds of another, practically paying the workmen to strike, that thereby they may keep down a rival production.*

Now it is obvious that by this policy of every man for himself and the devil take the hindmost, the value of coal lands as such is reduced down to nothing. It is only those tracts exceptionally rich and near the railroads or market that are worth anything, and that in proportion to these exceptional advantages. It is obvious, also, that labor cost will be whittled down to the lowest point.

Finally, from a geological point of view most important, it leads to a development of the resources that is a synonym for wastes. Instead of the coal being mined cleanly, the richest and handiest parts are gouged out, much left for pillars, as little timbering as possible done, and the rest left, perhaps in such condition that it can never be safely or profitably worked, certainly so that the total expense will be much greater than had a good job been done at first.

Let us get some figures of coal which we may be sure will be nearly minimum from those over-productive regions. Mr. W. J. Nicolls† gives the following items of cost as typical in the bituminous coal fields of Pennsylvania:

	Cents.	Cents.
5 per cent interest on capital invested.....	5	
Cost of haulage.....	7	
Cost of deadwork, drifts, shafts, etc.....	3	
Cost of superintendence.....	2	
Office expenses.....	2	20
Contract price to miners (35 to 40 cents).....	35	55
Royalty per 2,000 lbs.....	10	65

*Mineral Industry, 1897, p. 163, "the chief cause of the strike was that in a large part of the western bituminous fields, mine work is not regular, and the miners' wages are thereby reduced to a very low point. The existing coal mines of the United States could probably supply a demand 50 per cent greater than at present."

†Story of American coals, 1897.

The average selling price per ton of 2,240 lbs.* was 70 cents, or say 62.5 cents per 2,000 lbs., showing 2.5 cents loss on every ton raised. In other words, unless there was some profit from slack ignored by Nicolls, the royalty was too much.

According to Mineral Industry, 1897, the price of coal averaged in 1896 and 1897 respectively, 78 and 77 cents in Ohio, 66 and 67 cents in Pennsylvania. It is doubtful if there is a ten cent margin for profit and royalty and interest on capital at those figures. Orton, speaking for Ohio, says‡: "Our coal will never be properly mined or properly burned so long as it costs at the mine less than \$1 per ton. The question of waste demands immediate and serious consideration."

It will be noticed that the wages to miners are reckoned by the ton, and a weighman employed partially by the company and partially by the men, keeps track of the product of each miner. But there is a "fruitful source of discord"§ in the method of weighing the coal, as to whether it should be screened so as to remove the dirt and small coal before weighing or not, and if so how coarse the mesh of the screen should be. As the screened coarse lump coal is worth a good deal more than the screenings or "slack," (see Plate VI), and the size of the coal depends largely on the care of the men in getting it out and handling it, the operators used to insist on the coal being screened and paid only for that

passing over a certain sized mesh. Since, however, there has sprung up quite a demand for the smaller sizes of coal, pea coal, and buckwheat and so forth, the operators have begun to find much profit in this smaller sized coal, more if they could get it for nothing than in the larger, and to encourage its production, and many a controversy has turned on the size of the screen. In Sebawaing in the summer of 1897 there was a strike, the men demanding a 7/8 inch screen, instead of 1 3/4 inch as theretofore. It was settled, as seems to be the general tendency, by paying for the coal by weight before screening, or as it is called, "run of the mine." At present, however, the use of the 7/8 inch screen is universal in Michigan for basing wages. From a paper we gather the following statement of wages paid at Virden in connection with the notorious strike of 1898:

"Prior to the summer of 1897 the pay was 25 cents a ton, mine run. Some men had worked at 55 cents a ton, screened coal, which was about equal to 28 cents a ton, mine run, though the relative value of wages per ton, mine run, and screened coal, varies greatly in different mines, as some coal is much more fragile than others. In the strike the miners demanded 40 cents per ton, mine run."

*There is always a juggling in figures in coal over the long ton of 2,240 lbs and the short one of 2,000 lbs. It is a pity that the metric ton, which is practically the long ton, is not introduced to the exclusion of all others.

†Orton, Ohio, 1893, p. 269.

‡Orton, Ohio, 1886, p. 155.



Plate VI. Cars of lump and slack at Standard Mine.

The only remedy the operator has against workmen's carelessness in blowing the coal to pieces, in case the wages are based on the run of the mine, is to dock, fine or discharge them. On the other hand, various parts of the same mine vary so in brittleness that payments by amount of screened coal are very irregular and uncertain.

We notice from above figures that the rate of wages in the West is higher than in Pennsylvania, so that we must

replace the 35 to 40 cents a ton, mine run, (?) by at least 50 cents, to find the labor cost of mining in Lower Michigan.*

Something should also be added for the extra amount of water which will have to be handled, and we shall find from 75 cents to one dollar as probably what should be the minimum cost of mining coal in Lower Michigan. I doubt if this is attained in any mine; \$1.30 is nearer the mark still. The labor commissioner's report makes it \$1.38 in 1900. But of course much also depends upon the thickness of the seam. In Missouri a 22-inch coal seam is mined for four cents a bushel, i. e., one dollar per ton of 2,000 pounds clean coal, while in the Osage district a 14-inch coal costs about a cent more a bushel (\$1.25) in consideration of the difficulty of mining. As the entries and drift must be about the same height, no matter how thin the coal, the expense of deadwork† will also remain constant per acre, i. e., increase proportionally to the thinning of the coal when divided by the tonnage produced. It is said that a coal seam four or five feet thick can be worked as economically as one thicker, but as the seam becomes thinner the cost rapidly rises, and somewhere between one foot and two feet comes the thickness where it ceases to pay, depending on the price of coal, its freedom from sulphur, and other desirable properties. In Ohio‡ for every three inches decrease in thickness below four feet the miner was paid five cents per ton additional, down to two feet, no coal being mined except in rare cases below this thickness.

*A few years ago in Jackson and Corunna, according to Lawton's 1882 report, they were paying the miners 90 cents a ton for coal, and the cost was \$1.30 a ton, not including royalty. The scale price for 1901 is 86 cents per ton for pick mining of screened coal. See Michigan Miner, April, 1901, for complete scale.

†Lifting the fire-clay, taking out weak roof, known as draw slate, etc.

‡Orton, 1884, p. 847.

From the fact that in Missouri seams 14, 20 and 22 inches thick are worked and seams averaging two feet thick are assumed to make a profit of ten cents a ton at \$1.30, we may infer that there the limit of working is about a foot and a half, costing about \$1.30 to mine. The average thickness of the coal seams of Newcastle, England, is, according to the Encyclopedia Americana, three feet, and of the Pennsylvania bituminous area three and thirty-three one-hundredths feet. So we see, comparing the cost in Pennsylvania given above, that taking a three foot seam as a standard, the cost of mining is somewhere about inversely proportional to the thickness of the coal. If it cost 70 cents a ton to mine a three foot seam it would cost \$1.40 or thereabouts to mine a foot and a half seam and \$2.10 to mine a foot seam. (At Grand Ledge they were in 1899 paying \$1.10, mine run, per ton to the miners and selling the coal for \$2.00. The seam is about a foot and a half thick and there did not seem to be much profit in the business. In 1901 the price of coal was from \$2.30 to \$2.00 and the miners, each delivering his own car to the shaft or tippie, received 30 cents per car of 500 lbs.) Now as the price

of bituminous coal ranges in the Saginaw Valley between \$1.40 and \$2.10,* we are not surprised to find that beds 15 inches and 18 inches thick have been picked into here and there, but never put on the market in a large way. Taking the selling price to be as given above on the average \$1.42½, if we assume the royalty or profit to have been 10 to 15 cents a ton, which the report of the Mineral Commissioners indicate as a prevailing figure† the cost will be \$1.30, exactly what Lawton reports the cost of working at Corunna. But the probability is that the thickness of the coal mined averaged not over three feet. So it would not be safe to figure at present in Michigan on a cost of less than \$1.30 a foot for two and a half to three foot seam, though if the roof was good and sandstone "wants" and channels and faults not too abundant, and if the water could be easily handled, the cost might be cut down by nearly one-half.

*In 1887, \$1.41; in 1896, \$1.44, according to Mineral Industry, 1897, p. 161; according to D. A. Patterson in 1898, \$1.44; in 1897, \$1.46, and in 1896, \$1.62 at the mine. The report of the Commissioner of Labor for 1900 and 1901 makes the cost per ton for the entire output; in 1899, \$1.31; in 1900, \$1.38.

†Lawton, 1186; Knight, 1895, but in the Saginaw Valley, in spite of the better quality of coal there, 8 cents is a more prevalent figure.

§ 7. Scarcity value of coal.

We have discussed the cost of producing coal and we have seen that the thickness of the seam makes much difference, that while a three or four foot seam may not cost more than 70 cents a ton to mine, the thinner the seam the more the price will rise until a seam about a foot and a half thick will cost as much to mine as to ship from outside. We have pointed out the evils of over-production also. We now come to the question, how much coal is there in Michigan of the various thicknesses? Is it possible to break the market with coal, or must we to do this draw on coal so thin that it will be cheaper to import from Pennsylvania and Ohio.

The coal basin of Michigan has been supposed to cover from 6,500 to 8,000 square miles.*

*6,500 Keyes, Iowa, 1892; 6,700, according to A. Winchell, 1861, and U. S. G. S. 18th Annual Report, part 5, p. 353; 7,000 Mineral Industry, 1892; 8,000 Rominger, Geol. Sur. Mich. III, Pt. I, p. 345; 13,350 H. D. Rogers in Harper's Monthly XXIX, 1864, p. 163, Holmes, Mines and Minerals, September, 1899, 9,810 square miles.

As I have before remarked, its extent under the northern highlands is quite uncertain. Coal is well known to occur in Arenac county. Mr. Holcroft's men found coal fragments around the headwaters of the Tittabawassee and Salt Rivers, and Mr. T. T. Bates of Traverse City reports that his woodsmen found a ledge (boulder?) containing coal as far north as Roscommon county, and the wells at Gladwin and Big Rapids indicate that the coal extends considerably to the north of them. It certainly stops considerably south of Grayling. From the map (Plate I) we may estimate the area of the whole basin, including the Parma sandstone, as 11,234 square miles, though this estimate may be 500 square miles out of the way. But by no means all of this is underlain with

coal. We have to allow, as have geologists in other States, for various kinds of erosion which have cut out the coal, and not only for the loss through sandstone and drift channels, but for the coal made unworkable thereby. Orton in Ohio allowed 10 per cent. Any estimate can at the present state of affairs be but crude, but if I take a number of fairly reliable drill records from the various geological reports, those of the Saginaw Board of Trade and private sources, many put down for coal and likely to exaggerate it, but others for salt, etc., likely to neglect it, I find the following results: Out of 110 holes put down in the coal basin, 43 have not any coal reported (39 per cent.), 7 have coal seams, but probably less than a foot thick (6.3 per cent), 11 between one and two feet of coal (10 per cent), 20 between two and three feet (18.2 per cent), 12 between three and four feet (10.8 per cent), 17 over four (15.5 per cent). From this we may provisionally infer that 61 per cent of the basin is underlain with coal, but only about one-third of the basin with workable coal. Some drillers of experience tell me that even this is an over-estimate and only one hole in five or six is worth anything. To the figures given I may add from more recent data, that of 234 holes put down west of Bay City 46 (19.7 per cent.), show less than a foot of coal, 30 (12.8 per cent), between one and two feet, 65 (27.8 per cent), between two and three feet, 66 (28.2 per cent), between three and four feet, 29 (11.5 per cent), over four feet. These holes will give too high an average because where one hole has struck good coal, a number have been put down near it. On the other hand, they would hardly average to go half through the coal measures, so that there is undoubtedly some coal which they do not show. This coal will average 2.86 feet (west of Bay City, 2.4 feet) thick, or for the whole basin 1.75 feet thick. But if we take into account only the coal two feet thick or over, and allow but 1,000 tons to the acre to be yielded (and though modern practice can do much better, not much better is done in Michigan), and assume the area of the coal basin to be only 6,500 miles, we still have indicated 8,025,600,000 tons, nearly half in workable seams.* The greatest uncertainty in the situation is undoubtedly along the northern rim of the basin, where there may be much more coal than can be anticipated, or much less. One thing, however, is practically certain, the depth of drift and the consequent expense of development will be much greater. I think also that glacial erosion will prove to be greater.

*Even this may be too large, yet Pennsylvania with 9,000 square miles coal area is estimated in the Encyclopedia Americana to have 33,547,000,000 tons of bituminous coal, four times as much with an area of coal measures not 50 per cent greater and with only about twice the average thickness of the coal seam.

Now let us see what consumption we may count upon. The population of the coal basin was, by the census of 1890, 752,695, of the State, 2,093,899, and as the population of the State doubled in the interval 1870-1890, there must be about 1,000,000 people in the coal basin now. In 1900 the population of the state proved to be only 2,420,982. The consumption of bituminous coal in the United States was in 1889, 85,383,059 tons, valued at \$94,000,000; in 1890, 95,961,595 tons; in

1897, 147,557,980 tons; in 1899, 191,456,350; in 1900, 220,592,239 tons of 2,000 pounds†, while the population was in 1890 63,069,756 and in 1897 was supposed to be about 70,000,000. The census of 1900 made it 76,304,799. Thus for the United States in general two to three tons of coal were used per inhabitant, and at this rate we could consume two to three million tons of coal in the coal basin alone. I have not been able to find what the consumption really is, but surely much less. A vast amount of coal is consumed in a few industrial centers like Pittsburg, which raises the average for the United States. The Saginaw Valley has no city of the first rank, and the use of wood, slabs, etc., for fuel is hardly out of date. But as wood ceases to be used as steam fuel, and as glass, Portland cement, sugar and other large industries come in, we may expect the consumption of coal in the future to grow much faster than does the population. We can get minimum figures by taking the annual product for 1890, 74,974 tons, and adding to it amounts shipped in* by lake that year, viz., to Bay City, 84,000 tons; to Detroit, 90,000 tons; to Port Huron, 37,200 tons, and to Grand Haven about as much, i. e., about 300,000 tons. There was probably at least as much shipped by rail and to smaller ports, which we cannot estimate, but we see that the per capita consumption of coal was still quite low, probably not much more than half a ton per head of bituminous coal, and we see also that the domestic supply is but a fraction of that. Thus if coal can be produced in Michigan so as to drive out imported Ohio and Pennsylvania coal, there is a large market, and with proper industrial development there ought to be a chance to produce twice as much coal as at present without seriously breaking the price, provided the Ohio coal is sold as close as it can be and rates on shipping it in are not lowered. They are now only half to a third that charged for Michigan coal per ton mile, so that it is probable that the adjustment will be the other way, in favor of Michigan coal. However, there will always be some importation of varieties of coal having some especially desirable quality. It must also be remembered that lake freights are so low (25 cents to Cleveland) that the great coal shipping ports of Lake Erie are but a few miles off by rail.

†Eleventh Census report, and Mineral Industry for 1892 and 1897.

*U. S. Navy Department 1892, "Coaling, [Repairing and Docking facilities of the ports of the world," p. 8.

Ohio and Pennsylvania have immensely larger resources of coal,† so that if owing to any temporary glut of the Michigan market or strike there, our coal were to be exported thither it would be a sheer carrying of coals to Newcastle.

Thus we must look north and west of our own State (or possibly we might supply the Sudbury district in Canada) for our market.

†Ohio, 1884, p. 155.

The above estimates of the quantity of Michigan coal allow for a waste of over a third in mining, and, if the

resources of the State are husbanded and not given over to that form of development which is really squandering, greater waste can be largely avoided. The plan of a part of the Porter coal mine in Jackson (Fig. 5) shows the wastefulness of the old room or chamber system of mining and the amount of coal left in pillars, for only the part un-hatched was mined out. A foot of coal over an acre would yield,* as coal varies from 1,240 to 1,340 ounces per cubic foot in specific weight, on an average 1,752 tons. But it was not so long ago common to estimate only 1,000 tons to the acre, i. e., only 56½ per cent of the theoretically possible was available.

In Missouri, Winslow† figures on obtaining 1,250 out of a theoretical 1,700, i. e., five-eighths.

In Bristol, England, 1,500 tons to the acre are expected. Orton claimed that in 1884 the best practice gained but ⅔ of the theoretical amount. Agreeing with him, Professor Sperr of the Michigan College of Mines tells me that it was the custom to leave 40 per cent of the coal underground, and when some years ago the engineer of the Columbus, Hocking Valley & Toledo R. R. read a paper before the Ohio Society of Engineers, in which he claimed that 85 per cent could be saved, it was received with jeering incredulity. But now up to 95 per cent is saved, and in his estimates in 1893 Orton‡ allows only 20 per cent for mining loss. The leases of the railroad above mentioned provided that the lessor should mine all the coal. In England a distinct improvement in the amount of coal gained has been obtained by making the leases payable per foot per acre and not per ton extracted.

But for such good and economical mining it is necessary that there should be a profit on the coal. If the price falls too low the cheapest method of mining, no matter how much the waste, must be adopted. It is for this reason that Professor Orton was led to say, as above quoted, that no coal was ever properly mined or burned in Ohio at less than \$1.00 a ton.

The method of saving the coal most thoroughly is known as the long-wall system of mining, which in its application to the mining of thin seams with a weak roof is described by Winslow.§ It is probable that we cannot do quite as well in Michigan, as the shattering of the roof in caving would in many cases let in too much water. Again the long wall system to be effectively worked, requires a rather steady production, which very few Michigan mines have as yet attained.

*See tests of specific gravity in Table A.

†Mo., 1891, p. 49.

‡Orton, Ohio, 1893, preface p. x. estimates for Ohio 12,000,000,000 tons above drainage.

§Mo., 1891, App. A., p. 176.

As we have said a good deal concerning the waste of coal and other possible evils of a possible over-production, and as some one may blame us for not suggesting any remedies in case such evils appear, we shall mention those remedies that suggest themselves

as possible now, before any party feelings can be excited, for there is no immediate call for the application of any of them.

1. State ownership of the coal mines and control of the output as in Rhenish Prussia. This works very well.
2. Combination of the producers to fix output. This is generally known as a trust. No purely local combination could so check the output as to raise prices much above their present level, as the competition of imported coal is so great. Ohio coal now comes as far as Flint. This plan has been practically adopted by the chiefs of the anthracite trade and is preferable to unrestricted competition. Many of the mines near Saginaw now sell through one agent.
3. Regulation by a State supervisor, who should on the basis of the amount of coal consumed the previous year, and allowing a normal rate of increase of consumption, assign to each operating company its due proportion of the output, according to the amount of productive territory which it controlled, or number of producing shafts, making allowances for local demands or exports. This third plan has never been put in operation, so far as I know, but it would be practically a pool or trust with the pooling officer a State official. He should be a man of judicial and scientific character, and his duties would be in line with those of the Commissioners of Mineral and Labor Statistics, or the new Coal Mine Inspector, and if planned and worked, like the State Salt Inspection, with the good will of all parties, it would be a blessing all around. It would require a rare combination of abilities in the commissioner, and the chances are that he would soon find himself in hot water. Such a commissioner should try to keep the price up to a point where coal could be mined without actual loss down to 14 feet thick, and yet down below the price of imported coal. As the price of coal is likely to remain much less in Ohio and Pennsylvania than in Michigan and freight rates are low, he could hardly even by mistake or corruption so limit the production as to produce extortionate rates.

We may sum the situation up as follows:

- (1). Local production is at present only a fraction of local consumption (in 1896, 83,150. tons; 1897, 188,638 tons; in 1898, 290,711 tons; in 1899, 600,000 tons; for 12 months ending Dec. 1, 1900, 843,476 tons, but is very rapidly increasing. This original statement may be still true, though a good deal of our coal now crosses Lake Michigan.
- (2). If the industrial development is such that the local consumption becomes equal to that of the United States per capita, a four-fold increase of production will be taken care of.
- (3). But even 1,000,000 tons per annum, which will be reached in 1901, would imply but the mining out of a quarter section of four foot coal, so that over-production is quite possible.
- (4). The total product of the past (1,861,444 tons, up to 1898), is not an appreciable fraction of the resources.

(5). The local product should look to the local market, north and west.*

(6). Probably a sudden four-fold increase of present production would overstock the market.

PRODUCTION OF COAL IN MICHIGAN FOR 1900, BY COUNTIES.†

County.	Production. Short ton.	Value.
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	23,443	40,413
Total	849,475	\$1,259,683

PRODUCTION OF COAL IN MICHIGAN, 1880-1900.*

Year.	Production Short ton.	Value.
1880	129,053	Not given
1881	129,120	" "
1882	135,239	" "
1883	71,296	" "
1884	36,712	" "
1885	45,173	\$75,000
1886	69,424	90,651
1887	71,461	107,191
1888	81,407	135,221
1889	67,431	115,011
1890	74,977	149,192
1891	80,307	133,387
1892	77,890	121,314
1893	45,979	82,462
1894	70,022	103,049
1895	112,322	180,016
1896	92,852	150,631
1897	223,592	325,416
1898	315,722	462,711
1899	624,708	870,152
1900	849,475	1,259,683
	3,396,417	

*Events have verified this statement.

†From U. S. Geol. Survey, and State Labor Commissioner, whose bulletins one should see for latest statistical data. Product for year ending December 1, 1901, 1,004,104 tons.

§ 8. Value of coal royalties.

We are now within sight of the answer to our question: What is the value of the coal under the land?

If the land is in the basin and the chance is the same as for the basin in general an acre would contain 44.5 per cent of land with coal over two feet thick. This would for the whole area average 1.56 feet thick. Supposing this to cost \$1.30 a ton and sell for \$1.40 a ton, we could reckon on a profit of ten cents a ton, and allowing 2,500 tons to the acre to be available (1,600 tons per foot per acre) we should have \$250 as the value of the coal beneath an acre.

But this cannot be taken as its cash value, for the price may fall below \$1.40 and the cost may be above or below \$1.30. It is better to mine a little thick coal than the same amount spread out. Finally, and most important, by no possibility can the coal be all taken out immediately and the present value of \$250 to be paid in installments through a series of years is by no means the same as \$250 cash in hand. So that before we discuss its present cash value we must consider a little more closely the value of coal in the shape of royalties.

We have said above that under certain doubtful suppositions the coal may be worth so much a ton. If the coal is thicker it is worth more, if thinner less. The more information we have on this point the less of speculation and more of certainty the investment becomes. The more uncertain an investment the larger must be the prospective profit to tempt one into it, and thus we cannot expect a man to pay the full speculative

value of land. The more exploratory borings have been made the nearer we may expect to get the value indicated by the borings, and the higher the royalty which may fairly be demanded. These borings are part of the initial deadwork. The Michigan Miner says that one company has expended \$10,000 in borings alone.* So let us turn from theoretical and hypothetical data, and see what men have been practically willing to give. We have noticed that in Pennsylvania Nicolls assumes a royalty of ten cents a ton, and we find away off in Missouri Winslow assuming the same rate as the landowner's profit†. The Commissioners of Mineral Statistics give the royalties at Jackson and Corunna‡ at 10 to 15 cents for screened coal. I am told that at Grand Ledge 15 cents a ton is sometimes demanded. Some years ago in Ohio** they were paying 15 to 30 cents royalty on lump coal when they were paying miners 35 cents a ton (four cents more when the seam was less than four feet thick for every two inches below four feet). In Pennsylvania the Grirard estate which holds some very fine anthracite coal lands, reports a royalty of 30[^] cents and the Encyclopedia Americana reports as a common form of lease 25 cents a ton royalty, with 50,000 tons a year to be mined and fifteen years term of lease. Mines and Minerals quotes Pennsylvania bituminous coal lands at from \$25 to \$50 an acre, with royalties for non-coking coal from 5 cents to 12½ cents a ton. Mr. Ward says that 5 cents is a common rate.

*January, 1899, p. 10.

†Mo., 1891, p. 49.

‡Lawton, 1885, 1886, Knight, 1895.

**Orton, Ohio, 1884, p. 775.

As to whether the royalty is based on the ton of screened coal or not, we come upon the very same source of dissatisfaction, between the fee owner, and the operator who pays the royalty, that we found between operator and workmen. The operator has not the same reason for demanding payment to be only per screened ton and it will be found better if the royalty is upon the run of the mine. Five cents a ton, "mine run," will nearly or quite equal eight cents a ton on screened coal, though the proportions vary in different mines. It will then be more to the operator's interest to see that the coal comes out in as good condition as possible. Whereas, if there is a good demand for screenings and he gets them free of payment to the fee owner or miner, it might pay him to let the coal be smashed up, thus losing value for the fee owner, miner and community. Documents leasing the right to mine coal under a royalty† often provide that all the coal be taken (down to a reasonable thickness) and royalty be paid on the same. Otherwise there will be a temptation as the margin of profit dwindles to leave much of the coal in pillars where it cannot be extracted later, to save timbering, to the loss of the fee owner and the community. For this reason English authorities prefer‡ leasing coal by the acre, rather than by the ton, for it produces "better results for the landowner and closer

working by the operator, and of course a greater yield per acre."

†Seeman and Peters of Saginaw print a variety of forms of blank leases.

‡Encyclopedia Americana, p. 226.

To see that the operator does thus mine all the coal requires a survey from time to time (usually monthly; the old work does not all have to be done over again). But the extra cost is well repaid, and progressive States require the filing of mine maps in any case, since if more than one company has worked or is working in a district there is serious danger of fatal accidents from breaking into old water or gas filled workings.* Moreover the position of exploratory borings and artesian wells should be marked on the map for avoidance.

The question may arise as to other minerals or substances of value found in mining. For instance at one time they paid five cents a ton more for sulphide of iron in Jackson, than for coal. The fire-clay beneath the coal may also be of value. Ordinarily the presence of sulphide of iron will hurt the coal more than its independent value will amount to, and usually a certain amount of fire-clay will have to be taken in the deadwork to make entries high enough for hauling, unless the coal seam is extra thick, and the operator may well make all he can to eke out the profits of narrow seams. Other substances, such as iron ore, may at times have some value, but ordinarily the mineral rights for other substances than coal may be included with the coal.

It may be asked whether since the profits increase rapidly with the thickness up to four feet, the royalty should not also. While this is theoretically true, and in England they do thus survey the coal and lease it by the foot per acre, the extra expense of such a survey is considerable. A rough adjustment might be made according to the preliminary borings by decreasing or increasing the thickness of the coal which it was allowable to leave so that the average thickness of that taken should be two and one-half to three feet. Of course, if the coal were well known to be thick, a proportionally large royalty could be obtained.

It is, however, not uncommon to grade the royalty to be paid according to the selling price of the product, and this is eminently fair. In Appendix A is given part of a lease given in the iron business providing for a sliding scale royalty, which the Cleveland-Cliffs Company permit me to publish.

It is also the custom, as has been noticed above, to provide that the leaseholder shall mine or at least pay royalty on not less than a certain number of tons each year, so as to insure the fee-holder some steady income. It is obvious, however, that a large number of operators leasing independently of each other might be led to thus guarantee an output larger than the market could possibly take, and thus bring on the evils of over-production cited above. So that it is for the best interest of all to make this amount small, or waive it altogether if the price falls too low. As it is to the interest of the

operator to go ahead and get back the money invested in plant and deadwork as soon as possible, it will not ordinarily be necessary to force him ahead, while the exigencies of mining may make it more economical to mine now here and now there.

*The Sebewaing district is already in this predicament, and if the Pere Marquette No. 1, which is now shut down had not been mapped, it might be awkward for the Saginaw mine.

§ 9. Present worth of coal rights and royalties.

We come at last to consider what is the present worth or value of these royalties and leases for a term of years; in other words, of a body of coal which cannot be at once turned into cash. Suppose I am to get \$100 in a year. What is it worth to me now? Obviously the sum of money which at the current rate of interest will yield me \$100 in a year, i. e., \$95.24 at five per cent; but as there is a certain advantage in having my \$95.24 now, for I might prefer to spend it, or use it to save house rent, or in some other way in which it would earn more than five per cent, or at least I thought so, and as a bird in the hand is worth two in the bush, I should be likely to prefer the cash in hand unless the rate of interest were very good. Applying this to buying coal rights, we must also remember that many coal operators would be willing to go shares in profits in the shape of royalties on prospective profits, who would not have the cash to buy outright, or if they did would think they could earn a larger rate of interest upon it otherwise. Moreover, there is not nearly the risk involved in leasing on a royalty as in buying the land outright, and as men of smaller means can enter the competition for land it will often be more keen than for land to be bought outright. Thus a large discount from the value of coal as indicated by the customary royalties will usually be necessary to find its present worth.

Much also depends upon how quickly the coal can be mined. If the coal can all be mined in five years the return from royalties will be sooner and the present worth greater than if it takes the more ordinary term of a coal lease—15 to 25 years. The Star mine at Jackson was leased for a 30-year term at 15 cents royalty.

The following little table shows the present worth at five per cent of a royalty of ten cents a ton on 100 tons of coal, provided this royalty is divided into equal payments over a term of years, for various terms up to 60 years.

For other rates of interest the time over which the payments must be stretched to have a given present worth is in a rough way proportional to the rate of interest, e. g., if the rate of interest assumed were eight per cent and the payments distributed over (40÷8x5) 25 years their present worth would be about \$4.29.

TABLE OF PRESENT WORTHS. FIVE PER CENT.*

Terms of years.	Present worth of \$10 distributed in equal payments.
5	\$8 66
10	7 72
15	6 92
20	6 22
25	5 64
30	5 13
35	4 68
40	4 29
45	3 95
50	3 65
55	3 39
60	3 16

Now let us see what prices have been offered outright for coal lands.

Mines and Minerals had this to say in August, 1900: "Bituminous coal lands such as you describe sell in Pennsylvania at the present time for \$25 to \$50 an acre." . . . There are a great many royalty leases in this State and the royalties on bituminous coal, non-coking, vary from 5 to 12½ cents per ton. Coking coal royalties are higher, and we know of one such royalty of 17½ cents a ton.

In Missouri where Winslow estimates profits at ten cents per ton mined and 2,500 tons to the acre, coal rights are said to be† but a few dollars, seldom over \$5.00 an acre. The United States‡ demands for public coal lands \$20 an acre if within 15 miles of a railroad, \$10 if not within that distance. In Michigan offers of \$7.00 an acre are known to me. Now this last offer would mean at 5 per cent an equivalent to only 34 cents total royalty or 10 cents a ton royalty on 3.5 tons of coal per acre, and the production would last at this rate at 2,500 tons to the acre, 714 years. This production may seem absurdly small, and yet if we stop and think, it is far more than the pro rata share of the production or for that matter the consumption of the Lower Peninsula, for if we take the productive area of the coal basin as but 4,000 square miles, i. e., 2,550,000 acres, we see that the present production or consumption is but a fraction of a ton per acre. If, in other words, all the land of the coal basin were leased at 30 cents per acre royalty, the lessors would be bound to lose heavily. Thus for a tract to be worth for the coal rights \$7.00 an acre the buyer must depend upon exceptional advantages as shown in borings or other explorations, and on nearness to market. As long as the consumption is at the rate of only about a tenth of a ton per acre of coal land the present value of land for coal cannot average more than 20 to 30 cents an acre. The present value of any particular tract will vary from that, according as it is favored in nearness to market and shipping facilities, and as it is likely as shown by borings, etc., to be better or worse than the average, and the general value of coal lands will rise as the consumption of coal increases.

*The formulæ used are, if (y) is present worth, (c) total payment equally distributed over a term of years (x), and (i) the rate of interest:

$$y = \frac{c}{ix} \left(1 - \frac{1}{(1+i)^x} \right)$$

and if (u) is present worth at rate of interest (r) for the term of years (v), and if

$$v = x [\log (1+i) \div \log (1+r)]$$

$$= \text{nearly } x (i \div r)$$

then:

$$u = y [i \log (1+r) \div r \log (1+i)]$$

$$= \text{nearly } y.$$

From these formulæ it follows that the present worth if the rate of interest allowed is twice as great will be very nearly the same as though the payment were distributed over twice the period, and in the same ratio for other rates of interest. The table can also be used supposing that the royalties were paid at more frequent intervals, by replacing years by number of payments, and the interest that is earned between payments. For instance the present worth of a royalty of ten cents a ton payable semi-annually in equal installments for a term of ten years on 100 tons of coal would be at five per cent semi-annually \$6.22, the total payments on the royalty being \$10. Finally for longer terms than sixty payments the value of the present worth is nearly the total payment divided by the rate of interest and the number of payments.

†Mo., 1891, p. 50.

‡Law of Minerals and Mining in the U. S., p. 549.

APPENDIX A TO CHAPTER VI.

Extract from form of lease of Cleveland-Cliffs Mining Co., illustrating provisions for royalties on a sliding scale:

Royalty per ton.—*Fourth.* The second party shall promptly pay at the times hereinafter named, to the party of the first part, its successors or assigns, royalty on all iron ore, mined and removed from said premises or used thereon, during the existence of this lease, at the rate of not less than seven (7) cents per ton of 2,240 pounds, which royalty will vary with the price of the ore either market or actual as per schedule below. If the average market price of ore of like kind and quality at Cleveland, Ohio, upon dock at Lake Erie ports, for the three months preceding the month of payment, is from one dollar and fifty cents (\$1.50) to one dollar and fifty-nine cents (\$1.59) inclusive, then the royalty shall be eight (8) cents per ton; if such market price is from one dollar and sixty cents (\$1.60) to one dollar and sixty-nine (\$1.69) per ton inclusive, such royalty shall be nine (9) cents per ton, and so on according with the schedule of royalty; but if the lessee shall have actually contracted in good faith to sell ore from said premises, then the royalty on the quantity so contracted for or sold shall be determined by the actual prices of such contracts, it being understood that each grade of ore produced shall be treated by itself, and the royalty figured thereon, and that except on ore actually sold, the royalty shall be determined by the Cleveland market price for the like kind and grades as above provided.

Price based on Cleveland delivery.—It is further understood that royalties are always to be based on Cleveland prices, whether governed by the market or by actual sale, and if the ore is to be delivered at any place other than Cleveland, the difference in freight rates, if any, shall be added to or deducted from such contract price to determine the rate of royalty.

Examining records.—The second part., hereby agree., that said first party shall at all reasonable times, through its officers or agents, have full and free access to the books and accounts of said second part.. in order to determine the prices at which ore mined from the leased

premises has been actually and in good faith sold by the second part...

Copy of sales contract to be furnished.—Said second part.. further agree.. that each and all of.. sales contracts of said ore shall be executed in a sufficient number of original parts so that one original of every said sales contract can fee furnished to the first party and that will immediately on entering into any such contract, furnish said first party with such original part.

Arbitration.—In case any dispute arises between the parties hereto, as to market price of ores prevailing at Cleveland, Ohio, at any time, or as to the good faith of any sale of ore made by said second part, then, and in that event, all such disputes shall be left to the decision of three arbitrators, one to be chosen by each of the parties hereto on ten days written notice to the other party of its desire for such arbitration and before the expiration of said ten days, and in case of failure of either party to so choose within the time limited, then the other party shall have the right to select an arbitrator in lieu of the one so failed to be appointed by the other party, and any two arbitrators so chosen shall choose a third, and an award of any two arbitrators so chosen (which award shall be rendered in writing within a reasonable time after their appointment) shall be final and binding upon the parties hereto.

SCHEDULE OF ROYALTIES.

Price.		Royalty.	Price.		Royalty.	Price.		Royalty.
From	To		From	To		From	To	
\$1.50	\$1.49	7c	\$2.10	\$2.14	16c	\$2.55	\$2.59	25c
1.60	1.59	8	2.15	2.19	17	2.60	2.64	26
1.70	1.69	9	2.20	2.24	18	2.65	2.69	27
1.80	1.79	10	2.25	2.29	19	2.70	2.74	28
1.90	1.89	11	2.30	2.34	20	2.75	2.79	29
2.00	1.94	12	2.35	2.39	21	2.80	2.84	30
2.05	1.99	13	2.40	2.44	22	2.85	2.89	31
	2.04	14	2.45	2.49	23	2.90	2.94	32
	2.09	15	2.50	2.54	24	2.95	2.99	33

The above progression is to continue so that one cent additional royalty will be required for each additional five cents increase in price.

Seeman and Peters of Saginaw carry a number of forms of blank coal leases.

CHAPTER VII.
DEVELOPMENTS AND BORINGS.

The synoptical list of unpublished records and borings which appeared in the original report as printed in the Michigan Miner is here expanded by additions. The order of description is by counties, beginning at the north and west and proceeding south and east.

Missaukee County.—According to J. Smeltzer, wells down to 250 feet deep are all in unconsolidated deposits. No wells are known to penetrate rock and the extent of the coal measures is unknown.

Roscommon County.—Several authorities report coal found, e. g., T. T. Bates of Traverse City, and 4 to 10 inches of coal only 8 feet down, but on the other hand most wells down even to over 100 feet are in

unconsolidated deposits, and there are no reliable reports as to the extent of the coal. The abundance of coal in the drift shows that it must occur in the bedrock near by to the north and east.

Ogemaw County.—Rose City wells down to 260 feet show only unconsolidated deposits.

At 60 feet depth coal one foot thick is said to have been reached by the drill on the farm of Wm. Hodges, T. 22 N., R. 3 E.

In the extreme southwest township Mr. U. R. Loranger has put down three holes, of which the deepest probably passed at 277 feet 6 inches down into the sandstone beneath the coal series. A strong flow of water, which is said to have 25 feet head, was encountered in No. 1. The abundance of sandstone may be taken to indicate that the hole is close to the margin of the coal series. Only the southwest corner of this county probably lies in the coal measures.

HOLE NO. 1. (George's Lake.)

All surface (Pleistocene) deposits.

S. W. ¼ of N. W. ¼, Sec. 18, T. 21 N., R. 1 E., Ogemaw county:

	Feet.	Feet.
Yellow clay	4	4
Blue clay	15	19
Sand and gravel	21	40
Sand	20	110
Gray clay, soapstone	60	170
Gravelly clay	6	175
Sand	39	214

HOLE NO. 2. (Edwards Lake.)

S. W. of N. E. of Sec. 28, T. 21 N., R. 1 E.:

	Feet.	Feet.
Sandy clay	48	48
Sand	112	160
Red clay	10	170
Red sand	35	205
Red sandrock	6	211
Fire-clay	3'	211' 6"
Red sandrock	3'	215
Blue shale	1	216
Gray rock	22	238

HOLE NO. 3. (Chapman Lake.)

N. W. of S. E. of Sec. 32, T. 21 N., R. 1 E.:

	Feet.	Feet.
Stony clay	5	5
Gray clay	20	25
Gravel	5	30
Sand	65	95
Sandy clay	50	145
Sand	20	165
Gravelly clay	15	180
Red sand	10	190
White sandrock	5	195
Gray rock	3	198
White sandrock	2'	200' 6"
Gray rock	1'	202'
White sandrock	73	275
Dark gray rock	2'	277' 6"
Black shale	6"	278
Conglomerate rock (very hard)	4	282
Gray sandrock	3	285
Gray rock	30	315
Gray sandrock	3	318
Gray rock	20	315
White sandrock	88' 4"	408' 4"

Iosco County.—Black shale is reported from several of the Tawas City wells, and has given rise to the impression that coal is in the county, but the position of the Alabaster gypsum beds, and of the Arenac county limestones, shows that these cannot be the coal measures.

The coal supposed to have been found in the Oscoda salt wells is also black shale.

Lake County.—Wells are driven down to 150 feet deep in surface deposits. There are no records of rock wells.

Osceola County.—Wells even 300 feet deep do not touch rock and the extent of the coal measures is unknown.

Coal is however found quite abundantly in the drift, especially on the Middle Branch of the Muskegon in the N. E. part of the county.*

*Ewart Review, Aug. 16, 1901.

Clare County.—Near Harrison one well 102 feet deep is said to reach bedrock, but I doubt it. Most wells, even deep ones, are in unconsolidated deposits. At Clare a well 275 feet deep stops in quicksand and has failed to reach bedrock, and on Sec. 16, T. 17 N., R. 4 W., Mr. W. H. Shepherd went 270 feet mainly through gravel and sand, with specks of coal, without reaching bedrock. The probability of good coal somewhere in this county is great. It is probably very deep.

Gladwin County.—The Gladwin City water-works put down a well by Z. T. Mason, 275 feet to rock, striking a brown sandstone about 100 feet thick, which may be the same as Winchell's upper or Woodville sandstone, one of the upper sandstones above quite a series of the coal measures. On passing through it a black shale which turned the water bitter was struck, probably a coal horizon.

A large piece of drift coal was found 12 feet down, on Sec. 3, T. 19 N., R. 2 W.

Section 25, T. 17 N., R. 2 W., four miles south of Rhodes, Estey, Calkins and Sears are said to have put down a well 300 feet by the same driller, yielding a good boiler water, which rose within 12 feet of the surface, passing through strata as follows:

85	85	Clay.
90	5	Boulders.
140	50	Hardpan and red clay.
165	25	Blue shale rock.
170	5	Coal, but as this well was put down for water, not coal, this may not be closely accurate.
300	130	Shale, sandstone, etc.

Only 50 feet away was put down a hole in May, 1899, W. E. Caster, Driller.

Estey, Mich. Hole 50 feet east of tank.

Surface clay	.....	100	100
Hardpan	.....	5	105
Gravel	.....	32	137
Light slate	.....	4	141
Dark slate	.....	1	142
Coal	.....	1	143
Black slate	.....	2	145
Sandrock	.....	9	154
Blue sand shale	.....	11	165
Light sandrock	.....	2	167
Dark slate	.....	15	182
Coal	.....	1.5	183.5
Light slate	.....	4	187.5
Sandrock	.....	6	193.5
Light slate	.....	7	200.5
Dark slate	.....	9	209.5
Sand shale	.....	9	218.5
Black slate	.....	10	228.5

This record was furnished through W. H. Teed, Esq., and is not unlike those on Sec. 10, T. 17 N., R. 3 E. of Bay county, where we have coal with black slate above it at about 140 feet, and another at 180 to 190 feet, and down to 219 feet we are still in the coal measures.

Arenac County.—In the river at Omer (Sec 15, T. 19 N., R. 5 E.) coal measure sandstones with signs of

vegetation are exposed in the Rifle River, and there is said to be five feet of coal 86 feet down not far from Omer, but it is doubtful. On Sec. 1 of the same township and southeast therefrom Eocarboniferous limestones like those at Bayport are well developed. Up the Rifle River beds of the coal measures are exposed at intervals and have been more or less explored. The Lingula shales are shown. See Vol. III of these reports by C. Rominger, pp. 141 to 143, for account of explorations up the river to Sec. 3 of T. 19 N., R. 4 E.

Coal is said to have been found in T. 20 N., R. 6 E., near Turner, but with no roof.

In 1875 was the great Rifle River excitement. In the Saginaw Evening News for July 23, 1898, are some interesting letters regarding the matter. The statement is made that from Clyde to Pinconning, nearly every boring encountered coal from 30 inches to 8 feet thick. This is not likely.

In 1885* a shaft was put down near Sterling to a thin coal at 50 feet depth. A small seam is also said to have been struck on the farm of Mr. Firth at 125 feet depth.

At Standish Rominger describes a well:

52	52	Drift.
79	27	Sandrock.
106	27	Blue arenaceous shales with seams of iron pyrites and narrow bands of coal.
107 ft. 1 in.	1 ft. 1 in.	Coal.
121	1	Blue shales and fire-clay.
123	1	Sandrock and
129	1	Shale, was continued down, according to Rominger passing a thicker bed of coal, to 360 feet.

There are a number of deep flowing wells, and one well put down for brine to 1,900 feet. Mr. C. Jenkins of Jackson says there is but 5½ inches of coal at 178 feet at Standish. The general thickness and character of the coal series in this part of the county appears to be like that in Bay county, but perhaps with thinner seams. A report on Arenac county is in preparation by W. M. Gregory, which we hope to make a part of Vol. IX.

*Lawton, 1885, p. 177.

Newaygo County.—According to Mr. F. Wright of Fremont, no wells have struck bedrock in this county, even though over 300 feet deep, and at Newaygo one is 335 feet deep (i. e., bedrock is less than 330 feet above tide). Coal is, however, said to be not infrequently found in the unconsolidated deposits of the drift, which indicates the near presence of coal in the Muskegon Valley. This is confirmed by the Big Rapids well. There are also reports of sandstones exposed on the northern tributaries of the Lower Muskegon, but they may be of recent formation.

Near the southeast corner of the county at Grove, a well 260 feet deep has failed to reach bedrock. It is probable that the drift is very thick all over the county.

Mecosta County.—The only well known to penetrate the bedrock in this county, and there are many 200 feet deep or more, is the Red Cross well, put down by C. S. Mms for Mr. A. L. Clark, at Big Rapids. The depth to bedrock is given as 473 (also reported 500 and 600) feet. Flows of mineral water were noted at 600, 799, 831 and 1,300 feet. The casing is now down to 900 feet,

and the mineral water resembles very strongly those of Alma and Midland. It is unreliably reported that 4½ feet of coal occurred at about 600 feet. Bottles purporting to be samples of the strata were disowned by Mr. Nims, but appear on the whole to be from coal measure rocks. The depths of the flows of mineral water and of the Marshall seem to be parallel to those at Midland.

So far as this well indicates the coal is likely to occur under both Newaygo and Mecosta counties. Some drilling up the valley of the Muskegon, toward Evart would be an interesting speculation. Some fine flows would be encountered, and probably deep drift, quite possibly also thick coal.

Isabella County.—This county is without doubt near the center of the coal basin, and the coal measure series should attain its greatest thickness. But no well has penetrated the bedrock extensively. Generally speaking, wells find plenty of water, often flowing, at a depth of 75 to 200 feet and a number of deeper wells have not struck bedrock.

At Mount Pleasant, Dr. Getchell, originally boring for water, has put down on lots 3, 4 and 6, of block 31, a number of wells with the following results:

No. 1.		
At 50 ft.		No water.
65		Water in quicksand.
To 68	3	Hardpan or rock.
73	5	Very hard rock (limestone).
79	6	Coal.
84	9	Hard rock.
85	9	Sand, etc.
100	5	Water gravel.

No. 2 at the back of the same lot was the same as No. 1 to 68 feet, then not as hard, then between 73 and 79 feet there was but little coal, and at 80 feet with one foot at the bottom.

No. 3, across the way, 70 to 80 feet deep, did not show any coal to speak of. The question as to whether this is really coal in place, which is suggested by the presence of sand and gravel under it, is pressed by the fact that at the water-works just west a well 355 feet was put down by L. J. Lincoln without reaching bedrock, and there is a new test well about half a mile south 205 feet deep, and a well of F. Prince a little east of north 300 feet deep, all of which are said to be in the unconsolidated deposits. So that while coal may be expected near Mount Pleasant and it is said to be found loose in Chippewa River, and is also reported to be only 30 feet down on Sec. 22, T. 14 N., R. 3 W., it seems likely that the Getchell wells are not in solid rock. Any farther exploration should certainly be to the east.

There has been some drilling for coal on the Upper Chippewa, by Pickand, on Sec. 28, T. 14 N., R. 5 W., said to be only 60 feet deep, and unimportant, and also at Weidman, by S. Weidmann. Reports as to results are unsatisfactory.

Bedrock is presumably very deep.

Midland County.—At Midland there are about seven deep wells to the Marshall, i. e., 1,300 feet deep, more or less. Those to the northwest reach the bedrock sooner than those to the southeast, but at Coleman, a

well went through 72 feet hardpan and 204 feet of quicksand without reaching bedrock, while it is said that 2½ miles east one reached bedrock at 280 feet. According to Z. T. Mason, the Larkin well (reported in part in Vol. V) found 6 feet of coal, just at the very top of the rock at 200 feet depth, and P. J. Reardon's mineral well is said to be 198 feet deep and just to rock. On the other hand, the wells of H. H. Dow and the Midland Chemical Company go 285 feet to 300 feet to the rock, and the following record, which shows no coal, is an example of them:

285	285	Pleistocene.	Surface deposits.
318	33	Coal Measures.	Micaceous white sandstone, fresh water.
345	27		Black soft shale.
420	65		Sandstone, brine at 420.
455	35		Hard shale.
525	70		Sandstone.
575	50		Hard shale.
582	7		Hard sandstone.
700	118		Black shale.
745	45		Calcareous (Fe CO ₂) shale.
810	65		Black shale.
		Parma.	
920	110		White sandstone.
		Grand Rapids.	
970	50		Argillaceous limestone.
1050	80		Plaster bed, fairly pure anhydrite.
1130	80		Calcareous shale.
1205	75		Limestone.
1305	100	Marshall.	White sandstone somewhat ferruginous.

The black shales in above record may correspond to coal horizons nearer the margin of the basin.

Near Smith's Crossing, however, only four miles away, a coal field is just being developed, of which the following record may give an idea. It seems probable that these coals are the same as that of the Wolverine Coal Co. in Bay county (T. 14 N., R. 3 E.), and that they belong to the Verne coals.

Smith's Crossing, Midland Twp., Section 35 (Northeast quarter), T. 14 N., R. 2 E., elevation about 620 feet A. T.

Farm of Dougald Currie.

Clay	20 ft	20 ft
Sand	10	30
Clay	16	46
Quicksand	12	58
Clay	44	102
Sandrock	18	120
White rock	0 ft 10 in	120 ft 10 in
Red rock	2	122 10
White rock	2	124 10
Red rock	8	132 10
White rock	35	167 10
Coal	1	168 10
White rock	2 ft 6 in	171 ft 4 in
Coal	3 6	174 10
White rock	10	184 10
Sandrock, partly slate rock	10	194 10
White rock	21 11	205 9

A small vein of water passed through yielded a tablespoonful to a cup of salt (16 tablespoons to a cup), i. e., 5 to 10% of salts.

If the Smith Crossing coals at 168 to 174 feet are the main coal seam of the Bay county field, the Verne coals, then it is probable that the coal at 200 feet or so around Midland corresponds to the same horizon, which is probably equally deep near the Amelith shaft, so that the rest of the strata shown in the Midland section are additions to the base of the coal measures.

Further tests are said to show that the "coal" is slaty.

At Barnes', about 7 miles west, in T. 14 N., R. 1 E., rock is said to have been struck at 206 feet, with considerable coal above it up to 171 feet.

Near Sanford, T. 15 N., R. 1 W., was the old State salt well which is referred to in the Michigan Legislative documents, between 1840 and 1842, which was to have been 300 feet deep, but was really but 100 to 200, I understand.

In the same township were two borings by J. Russell, as follows:

On Sec. 4, T. 15 N., R. 1 W., June 3d, 1895.

Sand	16 ft	
Blue clay	21	37 ft
Quicksand	4	41
Clay, hard	25	66
Hardpan and gravel	37	103
Boulders	12	115
Clay and gravel	18	133
Boulders	10	143
Red clay	33	176
Sand and gravel	6	182
Sand and slate rock	5	187
Brown slate	4	191
Red sandrock	5	196
Sand and slate mixed	5	201
Water sandrock	47	248
Sandy fire-clay	4	252

On Sec. 27, T. 15 N., R. 1 W., April 22d, 1895.

Sand	7 ft	
Reddish clay	9	16 ft
Blue clay	3	19
Quicksand	2	21
Blue clay, hard	20	41
Sand	4	45
Hardpan and gravel	12	57
Very hard blue stone	—	—
Gravelly hardpan	17	74
Soft red clay	6	80
Sand and gravelly hardpan	37	117
Red clay	17	134
Alabaster or white rock	5 ft 6 in	139 ft 6 in
Red clay	24	164
Loose sandrock	1	165
Red clay	13	178
Red sandrock	18	196
Soap or soft slate	5	201
Hard slate	3	204
Sandy fire-clay	15	219
Dark slate	9	228
Poor coal	2	230
Rotten black slate	1	230
Light slate	3	233
Hard dark rock	1	235
Light slate	5	240
Water sandrock	14	254

Northeast of Midland, near Hubbard, explorations have been made for coal on Sections 24 and 25, T. 15 N., R. 2 E. The figures given me do not check exactly, but are about as follows:

Well No. 1, by J. Coreyll, for Midland business men, on McDonald farm, S. ½ of S. W. ¼, Sec. 24, T. 15 N., R. 2 E.

Sand	5 ft 6 in	
Light clay	7	82 ft 6 in
Blue clay	5	97
Gravel	6	93
Hardpan	97	180
Gravel	2	192
Hardpan	48	240
Gravel	1	241
Hardpan	8	249
Black slate	4	253
Slate	14	267
Coal	0	268

Well No. 2, on the Waldo farm (100 N., 800 W.), W. ½ of S. E. ¼, Sec. 25, T. 15 N., R. 2 E.:

Light clay	78 ft	
Hardpan	24	102 ft
Sand	15	117
Hardpan	5	122
Blue clay	40	162
Hardpan	7	169
Sand and gravel	22	191
Hardpan	4	195
Sand and gravel	5	200
Slate	25	225
Coal	2 ft 8 in	227 ft 8 in
Fire-clay and blue clay	11	238

Well No. 3, on Chas. Knorr farm (300 N., 400 W.), S. E. of S. E. of Sec. 25, T. 15 N., R. 2 E.:

Clay	80 ft	80 ft
Hardpan	22	102
Gravel	1	103
Hardpan	24	137
Gravel	2	139
Blue clay	15	154
Hardpan	10	164
Sand and gravel, with water	6	170
Hardpan	4	174
Quicksand	4	178
Sand and gravel	4	182
Hardpan	2	184
Sand, gravel and boulder	4	188
Hardpan	2	186
Sandstone	2	188
Sand and gravel	10	198
Hardpan	3	201

Well No. 4, Waldo farm (500 N., 1200 W.), S. W. ½ of Sec. 25, T. 15 N., R. 2 E.:

Clay	84 ft	84 ft
Hardpan	51	135
Sand	25	160
Gravel	8	168
Blue clay	10	178
Sand and gravel	12	190
Hardpan	8	198
Slate	40	238
Coal	1 ft 6 in	239 ft 6 in

Well No. 5, on Gerstacher farm (1000 N., 1500 W.), S. ¼ of N. W. ¼ of Sec. 25, T. 15 N., R. 2 E.:

Clay	88 ft	88 ft
Sand	2	90
Hardpan	24	124
Blue clay	19	134
Sand	5	139
Hardpan	63	202
Gravel, very coarse	6	208
Sand and gravel	6	214
Hardpan	10	224
Sand and gravel	6	230
Hardpan	4	234
Slate	38	272
Coal	2 ft 3 in	274 ft 3 in

These holes were put down by J. Coreyll, for a syndicate of Midland business men, and show about 200 feet of drift. The upper 70 or 80 feet are always of solid clay, probably lake clays which were deposited beneath the waters of the former great lake system, and will be found all over the Saginaw Valley. About 200 feet of drift seems to be the prevalent thickness in this region, outside of the valleys in the bedrock. There is a bed of coal two feet or less thick, at a depth of 230 to 240 feet. It seems quite likely that this is one of the Verne coals, at the same horizon as the 140 foot coal at Monitor, Bay county, for the country is probably higher and the indications are that the strata get deeper to the north and west around here. One hole went 257 feet and was still in drift.

Evidently the coal seams of Bay county extend into Midland county.

Bay County.—Coal probably underlies all of this county, but there is a brown sandstone which appears at the top of the series which I suspect lies in valleys and troughs cut out of the coal. For instance, Mr. Z. T. Mason reports the following well in Garfield township, 5½ miles due west from Lengsville, Sec. 26, T. 16 N., R. 3 E.

At top muck, then to 80 feet clay, beneath it stones and gravel, level of Linwood flows, then fire-clay and hardpan, 135 feet to bedrock; thence to 300 feet mainly brown sandstone, with a really soft water rising to within 5 feet of the surface. Contrasting this with neighboring wells, it seems likely that the sandstone cuts out and replaces part of the coal series. Other wells show a varied succession of beds, with a number of coal horizons; for instance, the following wells of Mr. Mansfield, on Sec. 10, T. 17 N., R. 3 E., and old borings by Mr. Holcroft on Sections 28 and 34 of the same township, which like wells at Estey in Gladwin county show coal horizons at about 140 feet and 180 feet and give promising successions of beds for the first two hundred feet or more.

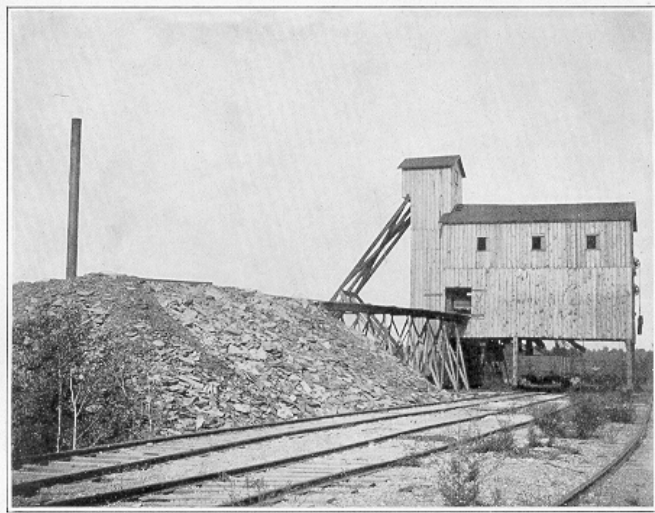


Plate VII. a. Tipple of Michigan Coal Co., Saint Charles.

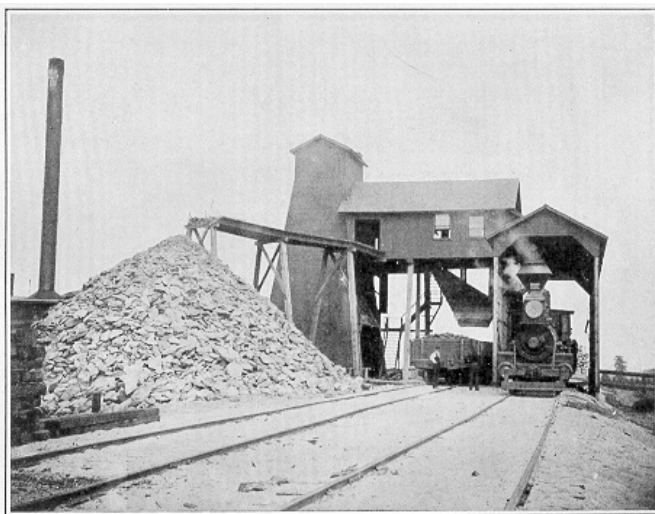


Plate VII. b. Tipple of Valley Coal Co., Bay City.

There are a very large number of coal records in this county which will be used in preparation of a county report. They are too many to include here, and some are not for publication yet. This remark applies also to Saginaw county.

The general record of the Bay City salt wells is given in Vol. V, but there is considerable variation in the depth of the Marshall, due to its undulations. Wells to rock run 80 to 90 feet deep.

Land of J. Mansfield, Sec. 10, T. 17 N., R. 3 E., S. E. ¼.

No. 2 is 1 foot higher than No. 1

No. 3 is 9 feet higher than No. 1.

NO. 1.		
Clay	80	80
Sand	4	84
Hardpan	8	92
Black shale	20	94
Blue shale	20	114
Black shale	13	132
Coal	2	134
Blue shale	15'	134½
Gray shale	10	150
Sandrock	5	160
Coal	5"	165
Black shale	9'	165' 5"
Coal	6"	174' 11"
Blue shale	10	175' 5"
		185' 5"

NO. 2.		
Clay	82	82
Hardpan	9	91
Black shale	1' 6"	92' 6"
Blue shale	15	107' 6"
Hardpan	15' 6"	123'
Sandrock	8	131
Hardpan	10	141
Sandrock	40' 6"	181' 6"
Coal	11½"	192' 5½"
Sandrock	14	206' 5½"
Blue shale	2	208' 5½"
Sandrock	2"	208' 11½"
Coal	3	209' 1½"
Blue shale	3	212' 1½"
Sandrock	6	218' 1½"
Blue shale	1	219' 1½"
Sandrock		

NO. 3.		
Clay	36	36
Gravel	1	37
Red gravel	1	38
Clay	52	90
Black shale	2	92
Hardpan	4	96
Black shale	3	99
Slate rock	4	103
White shale	4	106
Blue shale	21	127
Black shale	2' 9"	129' 9"
Coal	8"	130' 5"
Blue shale	25'	156
Sandrock	24	180
Coal	3"	180' 3"
Sandrock	5	185' 3"

Porter borings, Sec. 34, T. 17 N., R. 3 E., about 100 feet west of the center line and 5 feet north of the Pinconning and Glencoe logging R. R. track:

No. 1.		
Sand	6	6
"Clay containing gravel stones, coarse gravelly clay," i. e., till, "hard to drill, dried specimens looked like arenaceous fire-clay."	102	108
Hard arenaceous fire-clay, sand predominating	13	121
Argillaceous sandrock	1	122
Light blue shale	(13' 6"?)	136' 6"
Coal	1' 1"	137' 7"
Arenaceous fire-clay	8' 11"	146' 6"

NO. 2.

(Sec. 28 or 33, T. 17 N., R. 3 E.?) about a mile west farther up the road:

Soil	8"	8"
Sand, ochrish colored	7' 4"	8'
Clay, stiff gray and hard when dry	42	50
Clay, occasional blue streaks	11	61
Clay, fine grained, gray and hard when dry	26	87
Clay, fine grained, pinkish when wet	1	88
Clay, light blue	6	94
Clay, brown hard	6	100
Clay, bluish, a little sandy	7	107
Sandrock, ½ argillaceous	6	113
Shale, a piece of coal came up at about 114 feet depth	2' 6"	115' 6"
Breccia, hard, sand, clay and gravel cemented, ground runs between this and next, as is supposed	4' 11"	120' 5"
Shale, a layer of coal embedded in this shale about 2" thick and about 7" from the bottom. Tubing about 6½' from bottom	27	147' 5"

When we come to the southern part of the county it has been pretty thoroughly bored up for the first one or two hundred feet. We have between two and three hundred records, and there are, of course, a great many which we do not have. Many, perhaps most, of the records go only so far as to develop the upper or Verne coals, which are usually between 110 feet and 150 feet down and are shown in the sections of Plate IX. These seem to be comparatively level and persistent, and easier to trace, independent of the fact that we have many more holes through them. But there are some holes which help to show the lower measures as well. For instance, the following record, by Goff Paul, 1,000 paces north, 15 paces west, in Section 3 of Bangor, Township 14 N., R 5 E.:

Sand	11	0
Clay	71	82
Hardpan (till)	3	85
Quicksand and gravel	5	90
Quicksand and fire gravel.....	70	160
Slate	9	169
Hard rock	6' 3"	175' 3"
Black slate	11' 7"	186' 10"
Coal D. (middle rider).....	2' 1"	188' 11"
Fire-clay	27	215' 11"
Slate with streaks of hardrock, i. e., in part probably nodules of siderite.....	60' 4"	276' 3"
Black slate (C').....	11 0	287' 3"
Hard rock	3	290' 3"
Black slate	4	294' 3"
Coal C. (Saginaw seam).....	1' 2"	295' 5"
Fire-clay	30	325' 5"
Hard rock	2	327' 5"
Slate	20	347' 5"
Black slate	7	354' 5"
Coal (Lower rider)	0' 7"	355'
Fire-clay	18' 7"	373' 7"
Hard rock (limestone?).....	4' 8"	377' 3"
Slate	22	400' 3"
Black slate	13	413' 3"
Coal (Lower coal)	1' 9"	415'
Fire-clay	27	442'
Eocarboniferous:		
Hard rock	23	465'

According to reports through Shearer Bros., the Saginaw seam, coal C of the above record, is in places thick enough to work (4½ feet), in this region.

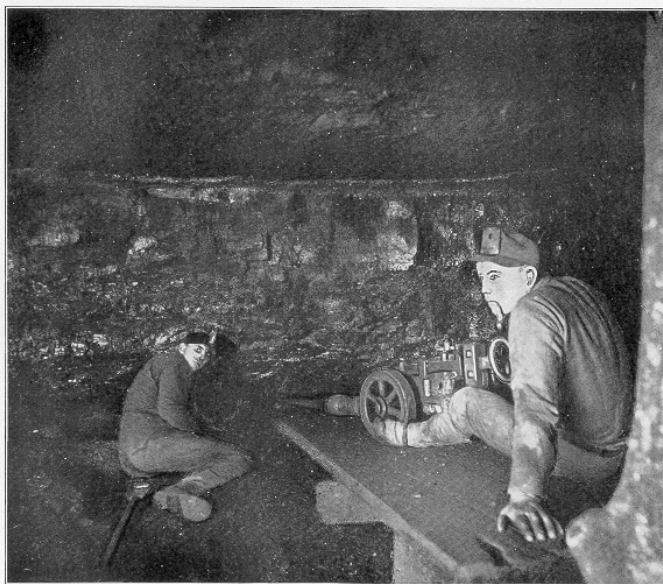


Plate VIII. Air coal cutting machine, Wenona mine.

The "hard rock" is probably mainly limestone, but sometimes perhaps nodules of siderite, pyrite, or indurated sandstone. I think that at 442 feet the Eocarboniferous formation is reached. According to Rominger's report the Parma sandstone is not marked at Kawkawlin, but gypsum was encountered at 400 feet. If such is the case, we may infer that the floor of the coal measures rises from the old Bay City city well (Plate VI of Vol. V) to the north, and so 442 feet of the boring just cited may correspond to 565 feet of that. I understand that it is true also in following the salt rock down the river toward Essexville that it rises. The deep wells around Hunger (that by Moses Thrash, for instance) show a heavy sandstone containing a very salt brine at varying depths from 348 to 265 feet down, which I take to be the base of the coal measures, in which case we may infer that the basement on which the coal measures rests rises in that direction also.

Not far away, on Section 36, a hole bored for N. P. Bradley with the Bullock diamond core drill gave the following record,* in which the base of the coal measures seems to come in at about 367 feet, and there

are unusually many coals in the lower part of the series and the Verne coals appear to be absent.

*Which I owe to the courtesy of the owner and the Sullivan machine Co., of Chicago.

Record of hole for N. B. Bradley with Bullock diamond core drill (3 inch) near Bay City, Mich.

(Sec. 36?, T. 14 N., R. 6 E.? near headwaters of Quannecussee.)

Date, 1889.	Time worked. Hours.	Formations.	Amount drilled.	Core saved.
June 7 to 13.....	10	Driving casing (Boulder core).....	80'	4' 6"
June 15.....	10	Drilling and churning.....	5' 85'	1'
June 17.....	10	Drilling and churning.....	3' 88'	2'
June 18.....	10	Drilling with bit.....	17' 105'	10'
June 19.....	10	Drilling with bit.....	15' 120'	11'
June 20.....	10	Drilling—pipe.....	10' 130'	8'
June 21.....	10	Light shale.....	10' 140'	8'
June 22.....	10	Dark shale.....	3' 143'	2'
		Sandstone.....	12' 155'	10'
		Dark shale.....	3' 158'	2'
		Sandstone.....	3' 161'	3'
June 24.....	10	Sand and shale.....	12' 173'	10'
June 25.....	10	Sandstone.....	6' 179'	4'
		Black shale.....	4' 183'	3'
		Gray slate rock.....	8' 191'	7'
June 26.....	10	Gray slate rock.....	4' 195'	3'
		Black shale.....	4' 199'	3'
		Black shale and sand.....	9' 208'	8'
June 27.....	10	Drove 7' 4" pipe.		
		Black shale and sandstone.....	7' 215'	6' 6"
		Sandstone.....	2' 217'	2'
June 28.....	10	Sandstone mixed.....	13' 230'	12' 6"
June 29.....	10	Black shale and fire-clay.....	7' 237'	6'
July 1.....	10	Black shale.....	3' 240'	13'
		Fire-clay.....	3' 243'	
		Sand and shale.....	5' 248'	
July 2.....	10	Dark shale.....	2' 250'	
		Dark shale.....	6' 256'	
		Coal.....	1' 257'	
		Sand white mixed.....	4' 261'	
July 3.....	10	Fire-clay.....	5' 266'	16'
July 4.....	10	Dark shale.....	18' 284'	18'
		Dark shale.....	8' 292'	
		Coal.....	1' 293'	
		Dark shale.....	2' 295'	
		Sandstone.....	8' 9" 303' 9"	19'
July 5.....	10	Fire-clay and shale.....	4' 307' 9"	
		Coal.....	6" 308' 3"	4"
		Sand and shale.....	6' 314' 3"	11'
July 6.....	10	Black shale.....	5' 6" 319' 3"	
		Black shale and clay.....	4' 323' 9"	
July 8.....	10	Black shale.....	3' 326' 9"	
		Coal.....	6" 327' 3"	
July 9.....	10	Soft white clay.....	5' 6" 332' 9"	8'
July 10.....	10	Black shale.....	10' 339' 9"	
July 11.....	10	Sand and shale mixed.....	3' 345' 9"	12'
		Dark shale.....	11' 356' 9"	10'
		Black jack.....	3' 359' 9"	
		Coal.....	1' 360' 9"	
		White sandstone.....	3' 363' 9"	
July 13.....	10	Blue shale and sand.....	3' 366' 9"	2'
		TOP OF PARMA?		
		Iron pyrites.....	1' 367' 9"	
July 15.....	10	Blue sand with grit.....	6' 373' 9"	9'
July 16.....	10	Sand.....	13' 386' 9"	10'
July 17.....	10	Sandstone pins.....	20' 406' 9"	12'
July 18.....	10	Same.....	20' 426' 9"	12'
July 19 and 20.....	10	Hard quartz.....	23' 449' 9"	16'
July 22.....	10	Setting bit and replacing rods.		
July 23 and 24.....	10	Sandstone.....	10' 459' 9"	7'
July 26.....	10	Sandstone.....	4' 463' 9"	3'
July 27.....	10	Repairing pump.		
July 29.....	10	Sandstone.....	10' 473' 9"	9'
July 30.....	10	Lime and quartz.....	10' 483' 9"	9'
		Same.....	12' 495' 9"	11'

The four coals of the report just given from Mr. Goff Paul on Section 3, Bangor Township, may be traced more or less continuously in Sec. 3, 4 and 10, rising to the south until the lower coal is only about 304 feet down. The lower rider (which here is the thicker seam) is only a few (six) feet above. At the center of Section 10 the base of the coal measures appears to be but 267 feet down, but in general it is near 400 feet down. These records do not show the Verne coals and their rider, and the records must be supplemented (p. 106) by those of the Handy Bros. and Wenona mine, which are less than a mile away.

In Section 19 another deep boring, not far from the Central and Michigan Mines on Sec. 25, enables us to see something of the lower formation here, to-wit:

Well of Peter Miller, W. ½ of N. E. ¼, Sec. 19.

Clay	81	81
Blue slate	29	110
Hard, sandy lime rock	7	137
Dark slate	20	137
Coal (Lower Verne)	2' 4"	139' 4"
Fire-clay	9	148' 4"
Slate	23	171' 4"
Hard rock	3' 2"	174' 6"
Dark slate	37' 8"	212' 2"
Black slate	5' 9"	217' 11"
Coal (Saginaw seam?)	2' 10"	220' 9"
Fire-clay	3' 2"	223' 11"
Blue slate	27	250' 11"
Light slate	19	269' 11"
Hard rock	3' 7"	273' 6"
Dark slate	21	293' 6"
Black slate	4' 5"	298' 11"
Coal (Lower seam)	1' 2"	300' 1"
Black slate	2' 1"	302' 2"
Fire-clay	4' 9"	306' 11"
Hard sandrock	26'	332' 11"

From this it is but little over a mile to the mines on Sec. 25 of the Central and the Michigan Mining Co. Thence southwest we can, through records furnished by the kindness of Mr. U. R. Loranger, trace the Verne coals quite continuously to the shaft of the Valley Coal Co. and the Amelith Shaft of the Pittsburg Coal Co., and thence to the Bay No. 1 and No. 2, the Monitor and Wolverine mines. The borings are, however, deep enough only to show the undulations and splits of the Verne group of coals, which sometimes split into three or four thin seams, and are usually from 110 to 190 feet down, 130 to 140 feet being common figures. (See Plate IX.)

The base of the coal series still appears to be not far from 400 feet down, say 388 to 444 feet, so that we appear to be still on the marginal shelf, Fig. 1, which borders the southeast side of the basin.

Huron County.—The coal in Huron county is practically confined to Sebewaing township. (See Fig. 9.) Streaks of coal and coal fossils are found elsewhere, as in the grindstone quarries, but there is no probability of finding coal, even though four feet of coal is said to have been found on the farm of James Chesney at 65 feet depth. The neighborhood of Sebewaing has been very thoroughly bored, and many wells have gone far beneath the coal to the Marshall sandstone to get flows. For detailed records see Vol. VII, Part II, p. 143 and following pages of the Huron county report, and also the column on p. 86 of Water Supply paper No. 31. The J. C. Likens Coal Co. has been recently organized, and is said to strike four feet of coal at 103 feet. There are but 40 to 60 feet of surface deposits immediately beneath Sebewaing, mainly lake clays, and two coal seams are found in the first 120 feet, though the lower one is not usually over 80 to 90 feet deep. The natural dip of the coal measures brings them to the rock surface a mile or two north and northeast of Sebewaing, while south and southeast they are cut out by a river channel which is filled with 150 feet or more of drift, and runs through Sections 15, 21, 20, 29, 31, T. 15 N., R. 9 E. The following record is as full and complete as any, but is only 30 feet from a well in which no coal was recorded:

J. C. Liken well, Sec. 18, Sebewaing. N. E. ¼ Sec. 18, T. 15 N., R. 9 E., May 19th, 1896.

Surface	51	51
Pleistocene		
Clay	1	52
Sand and gravel	2	54
Loose sandrock	2	56
Coal measures		
Hard rock	18'	74'
Dark sandrock	6"	74' 6"
Coal about	1'	76'
Sandrock	6'	82'
Slate	3' 8"	85' 8"
Bottom slate	1' 4"	87'
Parma		
Sandrock	13	100
Grand Rapids		
Light slate or sandy fire-clay	96	196
Hard dark rock	24	220
Slate	30	240
Hard lime rock	8	248
Napoleon. i. e. Upper Marshall		
Sandrock	55	303

Montcalm County.—The coal measures probably underlie the whole of this county, but we have absolutely no definite information concerning them. Coal has been reported, but under conditions that render it probable that it was in the surface deposits, in T. 10 N., R. 8 W., and at Amble, T. 12 N., R. 9 W., on the farm of N. Olsen, for the well was put down 360 feet by C. A. Denton, the driller, without reaching bedrock. Another well on Sec. 11, T. 11 N., R. 10 W., three-quarters of a mile S. E. of Maple Hill, 320 feet deep did not reach bedrock.

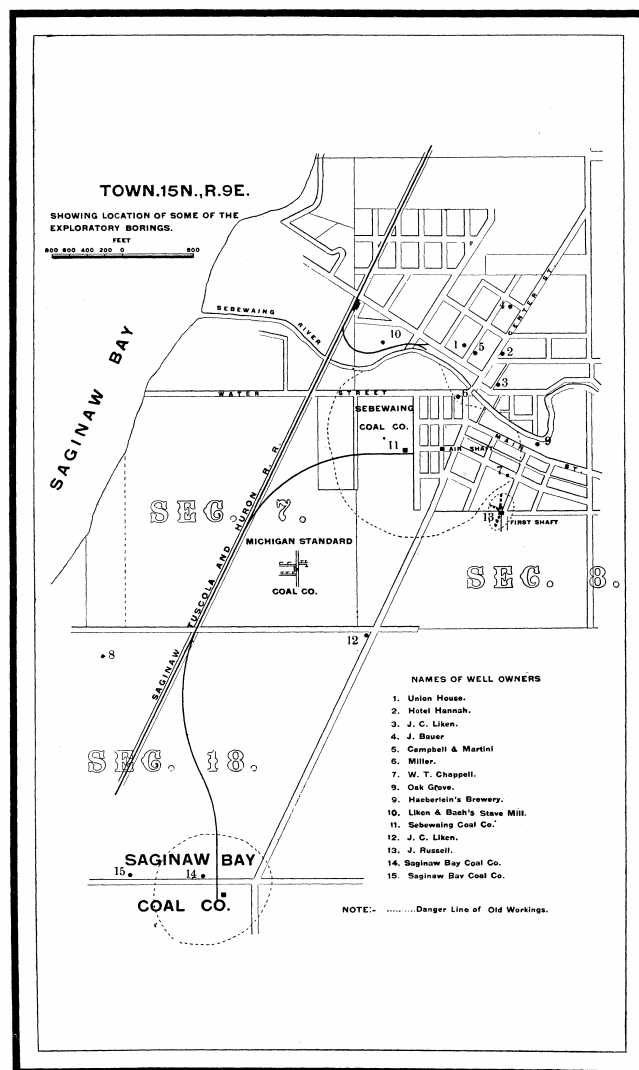


Figure 9. Sketch map of Sebewaing coal region, Town. 15 N., R. 9 E., showing location of some of the exploratory borings.

Gratiot County.—The drift seems to lie deep but irregularly over the northern part, as though heavily cut up by river valleys. For instance, it is but 335 feet to

rock at the Harrington House, St. Louis, while at Alma it is 500 feet. The record of the old St. Louis magnetic well, which only went through drift, is given by Winchell in detail (Am. Ass. for the Adv. of Sci., 1875, B. p. 31). The new Harrington House well has three casings and can yield three waters, the first an 8-inch, stopping at 100 feet in a nest of boulders; the second 6-inch, stopping at the level of the magnetic mineral water well at 255 feet in a nest of boulders with lots of water. Then there is a 4-inch pipe to 335 feet, the bedrock, which is red sandstone. Thence it is mainly white sandstone down to 599 feet, when they entered a white shale and stopped. The old St. Louis salt well, 1,314 feet deep, put down by Hardenburgh and Sager, was almost the same—surface deposits 337 feet, then 200 feet mainly sandstone.

Some thin coal has been found around Ashley at about 170 feet to 190 feet and deeper, but the bedrock surface here to is very irregular, from 50 feet dropping to over 200 feet in a mile or two north.

The Ithaca well has been given in p. 63, Vol. V. Several additional similar wells have been put down since.

On the farm of M. White at North Star coal is reported at 205 feet, and at 296, feet two miles east of Ithaca, on Wm. Dusch's farm, but bedrock was struck only a short distance above, at 292 feet.

The Alma well (Sec. 34, T. 14 N., R. 3 W., about 755 A. T.) is represented by a fairly full set of samples and an abstract of the record, summarized from that preserved by Prof. C. A. Davis, is as follows:

ALMA WELL.

Pleistocene.		
Clay and gravel with quicksand and water at 60 feet and 3 feet gravel at 157 feet.....	475'	475'
Sand and gravel.....	25'	500'
Woodville?		
Feldspathic sandstone (385-590 at St. Louis).....	50'	550'
Coal measures.		
Pyritiferous black shale, coal horizon.....	25'	575'
Blue shale.....	40'	615'
White shale.....	22'	637'
Pebbly sandstone.....	38'	675'
Shale sometimes black, coal reported.....	35'	710'
Parma.		
Pyritic sandstone.....	80'	790'
Grand Rapids.		
Blue and black sandy shales.....	70'	860'
Blue and white gypsum.....	35'	895'
Bituminous, dolomitic red or blue or argillaceous limestones (cement rock or hydraulic).....	120'	1015'
U. Marshall or Napoleon.		
Clean white sandstone.....	85'	1100'
L. Marshall.		
Red sandy shale.....	200'	1300'
Blue shale.....	20'	1320'
Red shales.....	200'	1500'
Coldwater.		
Blue shales.....	75'	1575'
Fine grained grit, no water.....	200'	1500'
Dark shales.....	70'	1675'
Blue shales, somewhat sandy down to 2,000 ft.....	595'	2250'
Berea Shale.		
Black shale.....	25'	2300'
Devonian.		
Blue shales.....	60'	2360'
Ohio Shale.		
Black shale.....	260'	2620'
Black shale with harder streaks.....	130'	2750'
Traverse.		
Dolomitic limestone.....	30'	2780'
Blue shale.....	20'	2800'
Sandy limestone, dolomitic.....	61'	2861'

Saginaw County.—So much boring has been done here that we can give but a few sample records. The deepest well of which samples are preserved is one put down February 10, 1862, by the Ann Arbor and Saginaw R. R. Co., at (Salina) South Saginaw, probably on the east side of Saginaw River, a little south of the center of Sec. 35, T. 12 N., R. 4 E., somewhere near where the F. & P. M. Belt Line bridge is. Corresponding horizons are about 50 feet deeper than at the old first well, as

recorded by Dr. Lathrop. It is noteworthy that in neither of these wells does the gypsum bed which we find at Bay City, Midland and Alma occur, and the interval from Parma to Marshall is less. We may give the record of the Salina well briefly as follows:

Pleistocene.		
Surface deposits.....	90'	90'
Yellow limestone.....	30'	120'
Blue calcareous shale.....	115'	235'
Marly limestone.....	70'	305'
Bituminous black shales (coal horizon).....	13'	318'
Green shale.....	22'	340'
Parma?		
White sandstone.....	145'	485'
Black shale.....	8'	493'
Unconformity?		
Grand Rapids.		
Arenaceous limestone.....	32'	525'
Impure sandstone.....	20'	545'
Calcareous green shale.....	25'	570'
Green shale.....	95'	665'
Argillaceous dolomite.....	25'	690'
U. Marshall or Napoleon.		
Leaves off in clean sandstone.....	25'	715'

*See also Water Supply Paper of the U. S. Geol. Sur., No. 31, Fig. 2.

We have also a detailed diagram of a salt well drilled by F. H. Mason, Bay City, for Gov. A. T. Bliss, Saginaw, at Carrollton Mill, drawn by A. C. McKinnon, Bay City.

5	5	Sand.
95	90	Blue clay.
120	25	Hardpan.
		6 in. pipe to here.
150	30	Limerock.
190	40	Sandy shale.
230	100	Sandrock.
300	10	Black shale.
375	75	Blue shale. Unconformity?
400	25	Sandy lime. Upper salt rock or Parma? Somewhere here there was a cavity where the drill dropped.
430	30	Sandrock.
480	50	Sandy shale.
540	60	Blue shale.
570	30	Sandy lime.
590	20	Blue shale.
592	2	Sandrock, 5¼ inch hole to here, where they probably shut off the gypsum.
625	33	Blue shale.
650	25	Limerock, very hard.
750	100	Sandrock, known as salt rock, that brine flows through; 4 in. hole to bottom. Napoleon sandrock.

There appears to be a dip of some 40 feet in the Eocarboniferous strata from Carrollton to South Saginaw, but the salt wells are deeper at Zilwaukee and deeper yet at Bay City. Thus we must have passed over an upward flexure in the Eocarboniferous, the top of which probably crosses the river on Sec. 24, T. 12 N., R. 4 E., near the Wylie Bros. wells.

The wells of the Brewer Lumber Co. and those at Mershon are but little over 700 feet deep, and the saline at the Germain factory, near the west ¼ post of Sec. 29, T. 12 N., R. 5 E., on ground nearly 20 feet higher, is said to be but 750 feet deep.

Below 398 feet in the First or Potter well, or 375 feet in the Bliss well, and 525 feet in the South Saginaw well, we are clearly in the Grand Rapids,—Eocarboniferous.

On the other hand, passing to the southeast, we find the South Saginaw wells deeper, 820 feet, and at Garfield and at St. Charles, as we have previously stated (p. 38) the Napoleon sandstone and the base of the coal measures are somewhat lower than at Saginaw. There is probably, therefore, something of an extra rise at Saginaw, of the Eocarboniferous strata, beside a general pitch to the northwest. To the southeast, toward Bridgeport, the Napoleon seems to rise but slowly, while the coal measures, judging from the wells of Hon. Henry M. Youmans, are at least 200 feet thick.

At Blackmar the Napoleon appears to be between 360 and 450 feet down, but there is no indication of the Michigan series above, or at any rate no line was drawn

between it and the coal measures. Moreover, Mr. Higgins' explorations found on Herpel's farm, about four miles away, near the center of Section 7, T. 10 N., R. 5 E., at least 200 feet of coal measures, as follows:

Test hole No. 6.	64 ft.	6 in.	64 ft.	6 in.
Surface	28	6	93	
Sandrock, which replaces a coal at 67 feet	26	6	120	
Black slate	23		143	6
Gray shale	1		144	
Sandrock	1	6	144	6
Gray shale	1		145	6
Coal	8		153	6
Fire-clay	5	6	159	
Light gray shale	15		174	
Dark gray shale	11		185	
Sandrock	2		185	2
Gray shale	6		191	2
White shale	7		198	2
Black shale	4		202	2
White rock (hard, probably limestone)....	5		207	2
Sandrock				

Also Mr. With's well in Tuscola county (which see), on the same general strike line, shows at least 279 feet of coal measures. Apparently, therefore, the Michigan series has really dropped out and the unconformity at the base of the coal series to which we have called attention is well marked. We cannot, therefore, use the stratigraphy of the Eocarboniferous "salt rocks" as a guide to our coal correlations, and since some of the lower coals may be more irregularly laid down upon this eroded surface than the upper, as indeed they are said to be in Indiana, Iowa and similar States, it will be well to begin our correlations at the top.

The coals which occur near the surface around Hunger, as may be seen from the table and correlation with the deep holes south of the Wenona and Handy Bros. Mines (Plate IX), appear to correspond to the Verne coals.

Section near Munger Station, 594 A. T.:

O. W. Blodgett's general section.	Blodgett's deepest, back of store.	Moses Thrash.
Quicksand.....16' to 18'	Surface.....89' 89'	Clay.....73'
Clay, blue or red solid.....70' to 90'	Shale.....46' 135'	Conglomerate.....28' 101'
Gravel.....6' to 8'	Sandrock.....2' 137'	Slate.....32' 133'
Hardpan.....2'	Shale.....2' 6" 139' 6"	Sandstone and slate.....23' 155'
Bedrock at about 2 miles east of Munger 3 1/4 feet of coal with no roof.	Slate.....1' 6" 141'	Whitish yellow shale.....22' 177'
Coal indications at (F).....142'	Black slate.....1' 1' 142' 1"	
Sandy fire-clay.....10'	Coal F.....1' 9" 143' 10"	"Graphite" i.e. soft black shale.....10' 187'
Coal at (E).....155'	Fire-clay.....158' 8"	Coal and slate D.....9' 196'
Sandrock 6' to 1' coal at.....175'	Coal B.....1' 5" 160' 1"	Hard conglomerate.....37' 233'
Fire-clay (D).....175'	Fire-clay, light, no grit.....161'	Coal and black slate C.....15' 248'
Dark sandrock with salt water, at about.....180'	Salty sandrock.....58' 219'	Sandrock.....3' 251'
for.....40' to 50'	Bl'k sandy shale.....31' 250'	Whitish slate.....54' 305'
Shale.....8' to 10'	Dark sandrock.....10' 260'	Blue slate.....25' 330'
Very salt sandrock.	Sandy shale.....5' 265'	Coal B.....2' 332'
	Sandrock, very salt.....32' 297'	Conglomerate.....10' 342'
		Coal A.....6' 348'
		Sandstone.....60' 408'

Now, Mr. Blodgett has traced them more or less intermittently down nearly to the county line, where at 115 feet and 151 feet there appear to be coal horizons, as well as lower down at 177 feet to 184 feet, just above a well-marked sandstone. We pick them up in Saginaw county in the well of Wm. Mayberry, on the S. W. 1/4 of the N. E. 1/4 of Sec. 3:

White clay	20	20
Blue clay	80	100
Soft rock	14	114
Hard rock	1	115
Coal (fresh water)	2' 6"	117' 6"
Rock	23	140' 6"
Coal	3	143' 6"
Hard rock with a brackish water.....	10	153' 6"

It is reported that there is coal in another well on the place at 200 feet depth, and extensive persistent and water-bearing sandstone for over 200 feet.

An imperfect record or two help to bridge the gap of two miles to the basin of coal which has been proved up around Arthur. From the records, for which we have to thank J. W. Messner, we select three:

NO. 3.		
Red clay	18	18
Blue clay	54	72
Hardpan	6	78
Blue rock	5	83
Slate	1	84
Coal (Verne)	3' 3"	87' 3"
Fire-clay	1' 1"	88' 4"

This coal occurs as thick as 42 inches, is usually from 90 feet to 100 feet down, and sometimes there are two, as in the following hole.

NO. 4.		
Red clay	18	18
Blue clay	56	74
Hardpan	8	82
Blue rock	9	91
Slate	0' 6"	91' 6"
Coal (Upper Verne) F.....	0' 10"	92' 4"
Fire-clay	3'	95' 4"
Blue rock	3'	98' 4"
Slate	1'	99' 4"
Coal (Lower Verne) E.....	2' 6"	101' 10"
Fire-clay	3' 8"	105' 6"
Blue rock	19	124' 6"
Sandrock	11	135' 6"
Blue rock	6	141' 6"
Slate rock	0' 6"	142
Coal (Middle rider?) D.....	1' 4"	148' 4"
Blue rock	8' 4"	151' 8"
White rock	9' 6"	161' 2"
Blue rock	7' 6"	168' 8"
Slate rock	1	169' 8"
Coal (Saginaw seam) C.....	1' 6"	171' 2"

NO. 5.		
Red clay	15	15
Blue clay	56	71
Hardpan	9	80
Blue rock	6	86
Sandrock	3	89
Slate	3	92
Coal (Verne) F.....	1' 8"	93' 8"
Fire-clay	2	95' 8"
Sandrock	24	119' 8"
Blue rock	20	139' 8"
Slate	3	142' 8"
Blue rock	7	149' 8"
Sandrock	18	167' 8"
Blue rock	8	175' 8"
Slate	3	178' 8"
Coal (Saginaw?) C.....	1' 9"	180' 5"
Fire-clay	4' 6"	184' 11"
Sandrock	12	196' 11"
Blue rock	2	198' 11"
Slate	2	200' 11"
Fire-clay	2	202' 11"

The following is a test well (No. 6) on the Oliver farm, Sec. 15, at Arthur, by J. Russell:

Red clay	16'	
Blue clay, firm	35'	51'
Blue clay, very soft.....	23'	74'
Hardpan	30'	104'
Loose sandrock	15'	119'
Black slate	2' 6"	121' 6"
Coal	2' 2"	123' 9"
Sandy fire-clay	1' 9"	125' 5"

125 ft. 5 in.

It is plain that the Blumfield correlations are rather artificial, especially that of the Middle Rider. It is possible that the thickest seam rolls between 100 feet and 140 feet depth and is continuous. From some points of view it is more likely that D of the record just cited is the Lower Verne and the coals above the, Upper Verne and Upper Rider respectively.

The development of the mine of the Barnard Coal Co. will probably settle the question. This mine is on the N. E. 1/4 of the N. W. 1/4 of Sec. 18, T. 12 N., R. 6 E., and the coal is about 140 feet deep. No tests of this coal, known as the Uncle Henry,* are yet known to me, however.

The following record of a hole put down by J. Russell for J. B. Peter on an adjacent forty-acre lot, the S. W. 1/4 of the N. W. 1/4 Sec. 18, T. 12 N., R. 6 E., shows the section down to the coal:

September 22, 1894.

Red clay	12'	12'
Blue clay	60'	72'
Hardpan and boulders	4'	76'
Hard sandrock	3' 6"	79' 6"
Sandy fire-clay	6'	85' 6"
Black shale	3' 3"	88' 9"
Coal	1' 6"	90' 3"
Soft light slate	1'	91' 3"
Soft dark slate	10' 11"	102' 2"
Harder dark slate	1'	106' 2"
Coal	1' 5"	107' 7"
Light slate	5' 5"	113'
Hard black slate	10' 7"	123' 7"
Coal, good	2'	125' 9"
Coal, poor	1' 11"	127' 8"
Bottom slate	2' 6"	130' 2"

If the three coals here shown are correlated with D, E, and F of Arthur and Hunger, then the Barnard or "Undo Henry" coal is the Middle Rider. In some ways it would be more natural to consider it the more persistent Lower Verne. But the quality is said to be better than in that seam.

Working west toward Saginaw, there are indications and records of coal horizons at no great depth all along, but the first boring of considerable depth and accurate record that we have is that of W. T. Chappell, on the farm of D. A. McDonald, on the S. W. ¼ of the N. W. ¼ of Sec. 16, T. 12 N., R. 5 E., as follows:

Clay	81'	81'
Hardpan	6'	87'
Sand and gravel	4'	91'
Sandrock	21' 6"	112' 6"
Gray shale	4'	115' 6"
Sandrock	61' 6"	178' 6"
Slate	4'	182' 10"
Coal (Saginaw seam)	0' 8"	179' 6"
Fire-clay	2'	181' 6"
Sandrock	46' 6"	227' 6"
Dark clay shale	44' 6"	273' 6"
Light clay shale	18'	291' 6"
Gray shale	8'	299' 6"
Sandrock	1'	300' 6"
Coal and rock (lowest coal)	1' 6"	302'
Fire-clay		
Sandrock		

*There is a Barnard Coal Co., limited in West Saginaw.

According to Mr. Henriett, the driller, a well which he put down 539 feet on the N. E. ¼ of Sec. 14, near by (T. 12 N., R. 5 E.), struck somewhere between 313 feet and 340 feet a rock with a 32° salt brine, which must almost certainly be the bottom of the series (292'-398' of the first well). Consequently, we may infer that the McDonald well is pretty nearly through the coal series, and the lowest coal struck is the lowest of the series.

Not very far away there is a well nearly equally deep. The record (the Gage farm on Sec. 9, T. 12 N., R. 5 E.) is interesting, for it shows no heavy top sandstone nor coal, as follows:

	Feet.	Feet.
Clay	86'	86'
Hardpan	2'	88'
Sand and gravel	2'	90'
Soft shale	12'	102'
Gray shale	69'	171'
Sandstone	2'	173'
Gray shale	10'	183'
Black shale	2'	185'
Gray shale	8'	193'
Black shale	15'	208'
Brown shale	13'	221'
Gray shale	17'	238'
Sandstone	13'	256'
Gray shale	2'	258'
Blue shale	10'	268'
Gray shale	12'	280'
Hard rock	1'	281'
Soft shale	11'	292'

At McDonald's we find mainly sandstone down to 178 feet. This sandstone probably appears also on Sec. 21, two miles south in Heavenrich's borings (from about 90 feet to 150 feet), where it is nearly clean enough for a glass sand. I think we are safe in assuming it continues to the Schaitberger and Eastman farms on Sec. 29, Wiggins' place on Sec. 33, and the Kochner farm on Sec. 3, T. 14 N., R. 5 E., though there it is split up with thin seams of coal.

It appears also to be the first rock met in the old salt well and in almost all the wells in the northeast part of Saginaw, e. g., that of the Bearer Block, and the numerous city wells, which find abundant water in the first 150 feet or less, so that I think we can trace it without break in continuity to the upper part of Eddy's well, near the river, 700 feet south of Genesee Ave. bridge, through a city well at the corner of Michigan Ave. and Davenport, which is in a heavy sandstone, and another at the corner of Michigan Ave. and Clark St. (coarse sandstone from bedrock at 91 feet to the bottom at 141 feet).

The lower vein of coal was found in all three holes, but variously split up. When we consider that the salt wells near by are less than 750 feet deep, we may be reasonably sure that this well is nearly through the coal-bearing series, and that the coal at 282 feet is not that of the Chappell-Fordney mine.

The Eddy well record is as follows:

NO. 1.			
Surface sand	28'	28'	
Clay	54'	82'	
Hardpan	48'	130'	
White sandrock	41'	171'	
Dark sandrock	12'	183'	
Black shale (Saginaw seam)	8'	191'	
Sandrock	1'	192'	
Hard slate	4'	196'	
Limerock	2' 6"	198' 6"	
Slate and sandrock	4' 6"	203'	
Coal (Lower rider)	0' 5"	203' 5"	
Fire-clay	7'	210' 5"	
Dark blue shale	64' 5"	274' 10"	
Dark slate	4'	279' 4"	
Coal (Lower coal)	3' 3"	282' 7"	
Shale and sand	6'	288' 7"	

Thus the correlation suggested with the first salt well seems proper.

Eddy's well brings us within two miles of the important coal basin of West Saginaw, in which the Pere Marquette No. 2, Chappell-Fordney and Riverside mines are located. If we go any further southwest, however, the upper sandstone is absolutely gone from the records with no trace. It apparently does not thin out to a feather edge, as if it rose above the coal basin. Especially on the east side are holes which show the sharp line. Neither does it dip down beneath the coal basin, at least there is no thick sandstone in the first two hundred feet or more. The fact that the salt wells deepen to the south makes it unlikely that the sandstone has, either by a fault or fold, passed above the line of the bedrock surface. The only alternative seems to be that it drops suddenly out, being a bar behind which the upper coals of the East Saginaw coal basin were formed, as shown in Plate IX.

As soon as we leave this capping sandstone the bedrock surface seems to dip to the west and the amount of drift becomes greater.

The Barnard,* Chappell-Fordney, Pere Marquette No. 2, Riverside, and Imperial mines are in the Saginaw seam. The three first are in the city limits of West Saginaw, the Riverside is opposite on the south bank of the Tittabawassee, while the Imperial is on Sec. 7 of James Tp.

*This is the Barnard Coal Co., limited, which has a shaft on the west side of Saginaw river. The tittle of the Pere Marquette shaft was

transported there bodily. Besides there is the Barnard Coal Co. operating about 6 miles east. Their coal is known as "Uncle Henry" coal.

A typical section in West Saginaw is the following:

	Feet.	Feet.
Clay	94	94
Hardpan	8	102

(The surface deposits are often over 150 and sometimes over 180 feet thick. The maximum depth within two miles of Saginaw is probably not less than 250 feet. In such cases of course the upper beds are cleaned out.)

Slate	18'	120'
Coal (Verne)	0' 3"	120' 3"
Fire-clay	2'	122' 3"
Gray shale	7'	129' 3"
Slate	4'	133' 3"
Fire-clay	6'	139' 3"
Slate	5'	144' 3"
Fire-clay	10'	154' 3"
Sandy shale	4'	158' 3"
Fire-clay	2'	160' 3"
Slate	8' 5"	168' 8"
Coal (Saginaw seam)	2' 7"	171' 3"

(This is the one mined. It is more usually near 200' deep where thick enough to work.)

Fire-clay	24'	195' 3"
Sandy shale	6'	201' 3"
Slate	11'	212'
Sandy shale	2'	214'
Slate	7'	221'
Sandy shale	7'	228'
Slate	14'	242'
Fire-clay	1'	224'

There are usually one or two coals, in the first 140 feet, of the type of the Verne coals, and when the Saginaw seam is extra deep—190, to 200 feet, there is apt to be some coal at about 160 feet. Two coals are said to be traceable in a general way, though with varying thickness, across James township and past Garfield to St. Charles, and there are enough holes to be pretty sure of their connection, with occasional barren areas, all over Sections 21, 22, 27, 28, 33, and 34. A Section E—W to Paines Station is shown in Plate IX.

The Saginaw seam appears to be the lowest coal seam shown in the boring of the Saginaw Board of Trade (S. G. Higgins' report) the record of which runs as follows, and was put down near the Palmerton Woodenware factory near the south end of the city, near the corner of Holmes and Brant streets (1,000 paces N., 200 W., Sec. 34, T. 12 N., R. 4 E.):

Test hole No. 10.

Lake Clays—		
Clay	70'	70'
Hardpan	2'	72'
Glacial Deposits—		
Sand and gravel	7'	79'
Hardpan	12'	91'
Sand and gravel	3'	94'
Hardpan	9'	103'
Sand and gravel	3'	106'

Test hole No. 10.—*Continued.*

Coal Measures—		
Blue shale	4'	110'
Gray shale	1' 6"	111' 6"
Black slate	6"	112'
Coal (Verne)	1'	113'
Gray shale	3'	116'
Sand and gravel	1'	117'
Gray shale	23'	140'
Coal (Middle rider)	6"	140' 6"
Fire-clay	5'	145' 6"
Light gray shale	4'	149' 6"
Sandrock	5'	154' 6"
Light gray shale	26' 6"	181'
Coal (Saginaw seam)	4"	181' 4"
Fire-clay	4'	185' 4"
Sandrock	2'	187' 4"
Gray shale	20'	207' 4"
Sandrock	13'	220' 4"
Dark gray shale	5'	225' 4"
Light gray shale	33' 4"	258' 8"

This is but little over half a mile from the Chappell-Fordney mine. It is very curious that the samples of the South Saginaw well should show so little coal when they

are between the well just recorded and the Saginaw coal mine shaft (See Plate V), the record of the exploratory boring of which ran as follows:

Clay	54'	54'
Sand and gravel, which turned out in the shaft to be a diagonal streak of a few inches	3'	57'
Clay	37'	94'
Sand	4'	98'
Hardpan to bedrock	5'	103'
Slate	1'	104'
Coal	1"	104' 1"
Gray shale	18'	122'
Slate	6' 6"	128' 7"
Coal	4"	129' 11"
Hard sandy clay	1'	129' 11"
Gray shale	5'	134' 11"
Strong black slate	12' 2"	147' 1"
Coal, this is the coal mined	3' 3"	150' 4"
Fire-clay	18'	168' 4"
Sandrock	34'	202' 4"
This sandstone may replace the lower coal.		
Sandy shale	3'	205' 4"
Slate	16'	221' 4"

This is a little south and about 1,700 feet east of the north quarter post of Sec. 31, T. 12 N., R. 5 E.

Though considerably higher I take the coal mined on the east side to be the same seam as that on the west side. The coal seams on the east side appear much nearer together and the main seam rises rapidly to the Pere Marquette No. 1 shaft near the center of Section 32, where it is but 135 feet down. Within one-half mile to the east it rises 22 feet more and comes too near the surface to be profitably workable, being in points on J. Stimson's farm covered by only four feet of soft roof.

Here we have the curious phenomenon of coal seams running up and abutting against a sandstone while a mile or two north their supposed equivalents appear to lie under it. This sandstone we may imagine to have been a northward travelling sand dune or bank—for this implies that the conditions of sandstone formation were gradually transferred from the former place to the latter, if we suppose the coal strictly contemporaneous. On the S. W. of Section 21, a mile and more south, are a number of holes drilled by M. and C. Heavenrich. Beneath the usual amount of drift, 95 to 102 feet, comes first a white sandrock, almost suited for glass sand, apparently the same as that first met in the McDonald wells on Section 14. This continues to 150 feet or more. Then in the next 30 feet are two or three quite persistent coal seams. Less than a mile away at Mrs. G. Schaitberger's place in the W. ½ of the S. W. ¼ of Section 29 we find the drift slightly deeper (115 feet), and the sandstone still present down to 145 feet. The Eastman farm, on the S. E. ¼ of Sec. 29 also shows the same sandstone from 103 to 156 feet, but with a foot of shale at 148 feet.

But the well of the O'Donnel Spencer Co., near the crossing of Genesee Ave. and the Pere Marquette R. R. (S. E. ¼ of Sec. 30) less than a mile away is entirely different, to-wit (A. M. McMillan, driller):

	Feet.	Feet.
Clay	72	72
Hardpan	43	115
Black shale	4	119
Coal	1	120
Soapstone	2½	122½
Coal	2½	125
Soapstone	45	170
Hard sandstone	8	178
Water bearing sandstone	6½	179½

This is the well that started the coal fields of Saginaw.

Again the well on J. Stimson's place in the N. E. ¼ of Sec. 32, not much west of the Pere Marquette R. R.,

begins in shale and soon strikes the coal mined in the Pere Marquette No. 1 shaft.

When the Eocarboniferous ceased to be a land surface, at the old salt well, sandstone was first formed there, apparently. The conditions of sandstone building seem to have moved to Carrollton and then back to the first salt well, where they were at the time of the Saginaw seam.

Returning to the Palmerton Woodenware factory on Sec. 34, we follow the Saginaw seam down on the Fitzhugh farm (Sec. 3 and Sec. 4, T. 11 N., R. 4 E.), where the Riverside mine is located, and the seam reaches 41 and 42 inches at about 182 feet, and there is also a seam at 158 to 163 feet. We cross, however, a deep gravel filled channel (or "washout") which at the Merrill bridge is over 150 feet to rock. It is a branch of the main channel, which is 250 feet or more deep between Shattuckville and Paines. One minor channel runs east towards the Standard mine, another runs south on Section 10. Another channel runs N. E. from Section 7, where the Imperial Coal Co. have a shaft about 180 feet deep in a basin of coal. Thence it is about two miles to the following well on Sec. 24, T. 11 N., R. 3 W.:

Surface	44'	44'
Hardpan	20'	64'
Gray slate	7'	71'
Sandrock	8'	79'
Gray shale	5'	84'
Gray slate	13'	97'
Coal (Upper Verne).....	1'	8"
Fire-clay	2'	100'
Gray slate	4'	105'
Sandrock	17'	122'
Coal (Lower Verne)	6"	122'
Fire-clay	6"	128'
Black slate	6"	135'
Fire-clay	3'	138'
Sandrock	1'	139'
Fire-clay	3'	142'
Gray shale	1'	144'
Blue slate	6"	144'
Gray slate	10'	154'
Sandrock	12'	166'
Gray slate	3'	170'
Black slate (Middle rider?).....	6"	170'
Gray slate	10'	181'
Black slate	4'	185'
Coal (Saginaw seam)	1'	2"
Fire-clay	2'	188'
Sandrock	9'	197'

These three coal horizons can be followed in a series of borings on Prairie Farm to the south through Sec. 25, and 26, though frequently one or the other drops out.

There is, as at St. Charles, at times "cannel coal" on top of the Saginaw seam. Coal also appears at 160 to 180 feet depth, a little above the Saginaw seam—the Middle Rider. The nearest record to the Verne mine on Sec. 23, which shows the coals in fair shape is the following on Sec. 16. (See Plate IX, section C.)

Clay	27'	27'
Hardpan	3'	30'
Sand	2'	32'
Hard clay	14'	46'
Gray slate	20'	66'
Slate	10'	76'
Sandy shale	10'	86'
Sandrock	37'	123'
Coal (Lower Verne)	6"	124'
Fire-clay	7'	131'
Gray shale	9'	140'
Sandrock	21'	161'
Slate	9'	170'
Coal	2"	170'
Sandrock	15'	185'
Gray shale	4'	189'
Slate	15'	204'
Coal (Saginaw seam perhaps).....	5'	205'
Fire-clay	6"	210'
Gray shale	6'	216'
Slate	6'	222'
Poor coal	1'	223'
Slate	3'	226'
Fire-clay	2'	228'
Sandrock	2'	230'

This brings us but two miles from the Verne mine, the section of which has been given.

About the same distance away we strike the explorations around Foster's. On Section 12 of Albee, there are the Verne coals probably at 86' 9" (1' 3") and 103' 9" (6") and another, probably the Middle Rider, at 156' 6" (1 foot).

On the farm of Mr. Herpel (Sec. 7, T. 10 N., R. 4 E.), Mr. Higgins gives the following records:

Surface	64'	6"	64'	6"
Sandrock	28'	6"	93'	6"
Black slate (Lower Verne).....	6"		93'	6"
A mile north there was 2 in. at 67' 8" and 3" at 83' 5"				
Gray shale	26'	6"	120'	
Sandrock	23'		143'	
Gray shale	1'		144'	
Coal	6"		144'	6"
(At 145' a mile north there was two inches of coal).				
Fire-clay	1'		145'	6"
Light gray shale	8'		153'	6"
Dark gray shale	5'	6"	159'	
Sandrock	13'		174'	
Gray shale	11'		185'	
Coal (Saginaw seam)	2"		185'	2"
White shale	6'		191'	2"
Black slate	7'		198'	2"
Hard white rock	4'		202'	2"
Sandrock	5'		207'	2"

Returning to the Prairie farm records and working southwest on Sec. 12, we have the following record:

Clay	47'	47'
Sand and gravel	9'	56'
Gray shale	52'	108'
Sandrock	35'	143'
Gray shale	6'	149'
Sandrock	51'	200'
Fire-clay	3'	203'
Slate	10'	213'
Coal	3"	213'
Fire-clay	4'	217'
Slate	16'	232'
Coal	4"	233'
Fire-clay	2'	235'
Gray sandrock	1'	236'

This is a hole of interest, not showing the Verne coals, but showing a heavy sandstone which is quite widespread around St. Charles, and is close above the Saginaw seam in the mine of the St. Charles Coal Co.

This sandstone is not persistent, for on the N. half of the S. W. ¼ of Sec. 15 we have borings of the Robert Gage Coal Co. The following is extra deep:

Clay	25'	25'
Hardpan	16'	41'
Slate	58'	99'
Coal (Upper Verne?).....	8"	99'
Other holes in the same 80 acres show a few inches of coal at 97' 3" and 106' 10" and 114' 6".		
Fire-clay	12'	111'
Sandy shale	40'	151'
Light shale	15'	167'
Coal (Saginaw seam?)	2'	170'
Other holes show 9" of coal at 153' 3" and 2' 5" at 157' 7".		
Other holes show 3' 10" at 168' 10" and 3' 3" at 166' 5", etc., north at the Robert Gage shaft it is down to 180' again.		
Fire-clay	15'	185'
Slate	20'	205'
Fire-clay	7'	212'
Sandrock	15'	227'

On the southwest ¼ of the northwest ¼ of Sec. 16, the sandstone we were speaking of reappears, however, as shown in this boring:

	Ft.	Ft.
Clay	22	22
Hardpan and gravel.....	18	40
Sand	4	44
Hardpan	8	52
Light slate	63	115
Sandrock, with streaks of slate	72	187
Dark slate	4	191
Sandrock	7	198
Slate	3	201
Coal (Saginaw seam)	4	205
Sandy fire-clay	9	214

This is close to J. H. Somers No. 2 shaft and a little over half a mile from that of the St. Charles Coal Co.

In this mine the sandstone was generally parted from the coal by a few inches of black slate, but to the north of the shaft the coal rises 22' in 150' and runs right into the sandstone. There are little streaks of coal and pebbles of Fe CO₃ in the sandstone which varies from 30' to 100'

thick. Such rolls account for the depth of the seam varying from 166' to 200' and a little more.

Similar pebbles of Fe CO₃ are found in a sandstone at Williamston and elsewhere.

None of the above records show the Lower Verne well developed, but in the Robert Gage shaft near the west ¼ post of Section 15, T. 10 N., R. 3 E., there were three small coal seams above the main Saginaw seam, and in the shaft of the Michigan mine near the north ¼ post of Sec. 8 (Black Pearl, Plate VII), where the main seam is about 190 feet down, there were 20" to 30" of coal at 128', which were mined at first but spoiled the quality of the coal, for it contained much more sulphur than the lower coal. The same seam occurs in the J. H. Somers No. 1 shaft on Sec. 3. It is said to be more pockety and irregular. The following test holes by the Higgins committee show this in the record. No. 11 is about 10 rods west and No. 13 is about 30 rods north of No. 12.

No. 11.		No. 12.		No. 13.
Sand.....	8'	10'	10'	
Clay.....	13'	21'	20'	30'
Gravel.....	1'	22'	1'	sand..... 31'
Clay.....	25'	47'	17'	sand..... 48'
Gravel and sand.....	1'	48'	1'	sand..... 49'
Blue shale.....	37'	85'	46'	clay and shale. 95'
Hardpan and gravel..	2'	87'	10'	gray rock.....105'
Light gray shale.....	13'	100'		
Sandrock.....	12'	112'	25'	130'
Coal.....	2"			
Upper Verne?				
Gray shale.....	2'	114'	6'	136'
Coal.....	2"	114'	2'	136'
Lower Verne?			2'	138'
Fire-clay & sandrock	22'	146'	5'	143'
Gray shale.....	2'	148'	11'	154'
Black slate.....	3'	151'	1'	155'
Place of Middle Rider?				
Gray shale.....	4'	155'	26'	181'
Dark gray shale.....	3'	158'		
Light gray shale.....	14'	172'		
Brown slate.....	7'	179'	6'	187'
Black slate.....	2'	180'		
Coal (Saginawseam),	2'	182'	6"	189'
Salt.....	1'	183'		
Fire-clay.....	1'	184'	6"	189'

It is said that southwest of No. 12 the upper coal is 18 inches thick; that 40 rods east it is about 2 feet thick, and that 30 rods east of south there is 2' 6" at 123' 2".

Before leaving St. Charles it is well to call attention again to the fact that the seam now worked is not the lowest of the coal measures. Unfortunately I have no accurate record of the beds below exposed in the salt wells recently put down, but I am authoritatively informed that from 500' down there was a good deal of the limerock of the Eocarboniferous (as at Garfield), and at about 425' the last coal seam was struck, a few inches thick, while the Napoleon is from 700' to 810'.

Thus the lower seams are present as they are around Bay City, though as yet we know very little about their thickness.

The Saginaw seam can be followed north from St. Charles and west from the Prairie farm explorations already mentioned, varying in thickness but at about the same level or deeper. The upper coals also persist, as is shown by the following record of a hole close to the old salt well at Garfield, A. W. Johnson, driller.

Surface sand	3'	3'
Blue clay	15'	17'
Hardpan	42'	59'
Sandrock	8'	67'
Sandy shale	63'	130'
Coal (Upper Verne)	1'	131'
Fire-clay	2'	133'
Slate	5'	138'
Coal (Lower Verne)	4"	138'
Sandy fire-clay	12'	150'
Sandrock	2'	152'
Water bubbled up and the casing was magnetic so that callipers clung to it.		
Slate	45'	197'
Sandrock	14'	211'

This possibly may not have gone quite far enough to strike the Saginaw coal, which appears in a hole a mile east on the S. W. ¼ of Sec. 15, T. 11 N., R. 3 E., whose record runs:

Blue clay	40'	40'
Hardpan	20'	60'
Very hard rock	8"	60'
Soft sandrock	1'	62'
Gravel	2'	64'
Bedrock here—		
Sandy shale	70'	134'
Verne coals absent—		
Light slate	30'	164'
Dark slate	20'	184'
Coal	2'	186'

These two holes are quite comparable with the hole on Sec. 24, T. 11 N., R. 3 E., whose record we have cited just above.

If we go much farther north the bedrock surface begins to drop off into the deep channel which runs west from Saginaw. For instance at Paines we have the following record:

	Feet.	Feet.
Surface to bedrock.....	208	208
Coal, perhaps the Saginaw seam.....	2	210
Soft sandstone	32	242
Soft sandstone	20	262
Dark shale	28	290
Sandstone	32	322
Black shale	30	352
(Probably the horizon of the lower coal.)		
Fire-clay	2'	354'

Four miles north it usually runs from 225' to 240' to bedrock. In the west part of the county the bedrock surface is deep.

For this reason the northwest part of the county has been comparatively little explored. The following, however, is the well put down by J. H. Whitney on the N. ½ of the S. W. ¼ of Sec. 24, T. 12 N., R. 1 E. No. 1 was put down on the S. W. ¼ of the S. W. ¼ of Sec. 26.

Clay	8'	8'
Sand	6"	6"
Clay	26'	35'
Sand	20'	55'
Clay	16'	71'
Sand	5'	76'
Soft clay	34'	110'
Sand	7'	117'
Soft clay	25'	142'
Clay	2'	144'
Dry sand and gravel	15'	159'
Clay	15'	174'
Sand	2'	176'
Sandrock	8'	184'
Gray soft shale	1'	185'
Sandrock	2'	187'
Sandy shale	2'	189'
Sandrock	3'	192'
Gray shale	5'	197'
Sandrock	4'	201'
Coal (possibly the Saginaw seam).....	1'	202'
Sandrock	4'	206'
Sandy white shale	9'	215'
Sandrock	20'	235'
Sandy shale	30'	265'
Sandrock	30'	295'
White sandy shale	20'	315'
White sandrock	7'	322'
Dark gray shale.....	6'	328'
Dark sandrock	5'	333'
Dark shale	5'	338'
Sandrock	1'	339'
Gray shale	3'	342'
White sandrock	2'	344'

Thus in passing west though we know that the Eocarboniferous strata are dipping that way, we can find no more trace of a general dip of the coal-bearing series than we did in Bay county. The general level of the country is rising.

In the southeast part of the county the distance to bedrock is not usually great, some 60 to 100 feet, and

sandstone with plenty of water is soon obtained. Some coal is found, but apparently not enough to attract investment.

Tuscola County.—A detailed report upon this county is in preparation by C. A. Davis, to which reference must be made for more detailed information. There is quite a little coal around Unionville at 118 to 130 feet.

On the other side of the valley, which cuts out the coal southeast of Sebewaing, we find the coal reappearing and extending through Columbia and even into Elmwood. This is shown, for instance, by the well of T. McCarty on the southeast quarter of Sec. 24, T. 14 N., R. 9 E., in which under about 84 feet of blue clay and 14 feet of sandstone, 3 feet of coal was said to have been met. I saw some of the coal. There was water in the sandstone.

The coal beds seem to be mainly confined to the part of the county northwest of the Cass, though there may be isolated patches to the south in T. 10 N., R. 7 and 8 E., especially since two foot seams of coal are reported from Vassar at 82 feet and 126 feet.

The recent well at Caro, 15 feet above Cass River, struck under 113 feet of surface deposits, a limestone which appears to be Eocarboniferous, and very much like the Bayport limestone, though there are two feet of black shale at 240 feet, the record being (A. J. Scott, driller):

Drift	113 ft	113 ft
Limestone, compact, pyritiferous	7	120
Green shale	25	145
White sandstone, with water	40	185
Dolomitic limestone	5	190
White sandstone	50	240
Black shale	2	242
Calcareous sandstone	10	252
Black shale	1	253
Sandstone, greenish white, kaolitic, with coaly specks and calcareous layers	29	282
The flow is strong and the water very slightly brackish.		

The thickness increases probably quite fast to the northwest. The following record, by J. Russell on Sec. 4, T. 13 N., R. 9 E., is a rather full one and the base of the coal-bearing series appears to be at 170' 3":

Red clay	11'	11'
Blue clay	49'	60'
Hardpan	15'	75'
Soap rock	14' 6"	89' 6"
Hard streak	6"	90'
Water here.		
Slate rock	27'	117'
More water.		
Black slate rock	11'	128'
Light slate rock	2'	130'
Dark sandrock	5' 6"	135' 6"
Hard black slate	6"	136'
Sandrock	4'	140'
Black and white rock mixed	1'	141'
Fire-clay or white rock	3'	144'
Black and white rock mixed	1'	145'
Sandrock	9"	145' 9"
Coal	1' 8"	147' 5"
Dark slate rock	1'	148' 5"
Light slate rock	1'	149' 5"
Fire-clay or white rock	2"	150' 7"
Light slate rock	1' 1"	152' 8"
Dark slate rock	6' 7"	159' 3"
Light slate rock	11'	170' 3"
Eocarboniferous.		
Lime rock	20'	190' 3"
Sandrock	18'	208' 3"

The base varies a good deal with the depth. When the Eocarboniferous limestones do not come until a considerable depth, heavy sandstone sometimes occurs, with some coal above or below it.

This is illustrated in the following records:

	Sec. 18, T. 14 N., R. 9 E.		Sec. 18, T. 14 N., R. 9 E.	
Clay	67'	67'	68'	68'
Hardpan	10'	77'	7'	75'
Sandrock	25'	102'	99' 4"	174' 4"
Slate	13'	115'		
Coal				
Sandrock	55'	170'		
Coal			3' 1"	177' 5"
Hard gray sandrock	18'	188'		
Slate rock	5'	193'	6'	183' 5"
Light slate	6' 7"	199' 7"	Sandrock 4'	187' 5"
			Lime	191' 5"

Compare also the following record No. 8 of Mr. Higgins' series of tests:

Surface	47'	47'
Blue shale	7'	54'
Light gray shale	2'	56'
Dark gray shale (Verne coal horizon?)	21'	77'
Sandrock	112'	139'
Gray shale with layers of coal (Saginaw seam)	3'	202'
Soft fire-clay	6"	
Hard fire-clay	3'	206'
Red sandstone with layers fire-clay	18'	224'

A large amount of records in Tuscola county have been preserved, more than can be printed here.

This is a fair illustration of the tests around Tuscola, which Mr. Zagelmeyer says run up to 80 feet of drift, then 160 feet of white sandrock, then 6 to 22 inches of coal under the sandrock. This sandrock probably outcrops in the river, and coal also occurs above it; which is probably one of the Verne coals.

It is not far, however, to F. With's well, near the S. W. corner of Sec. 30, T. 12 N., R. 7 E., where this thick sandstone has begun to break up, though water comes in freely at 150 to 200 feet. The record is:

Clay	56'	56'
Hardpan	28'	84'
Sandy shale	32' 4"	116' 4"
Blue shale	12' 4"	128' 8"
Black shale	1'	130'
Gray shale	24'	154'
Black shale	1'	155'
Hard sandy shale, water along here	11'	166'
Gray shale	6'	172'
Very hard sandy shale	18'	190'
Sand not so hard	12' 8"	202' 8"
Gray shale	1' 4"	204'
Hard sandrock	8"	212'
Black shale (Horizon of Saginaw seam?)	10"	212' 10"
Sandrock	2' 2"	215'
Black shale	2' 4"	217' 4"
Fire-clay	2' 3"	220'
Hard sandrock	6'	226'
Black slate	1'	227'
Fire-clay	2'	229'
Blue shale	3'	232'
Coal (Lower Rider or Saginaw)	8"	232' 8"
Fire-clay	2' 1"	234' 9"
Blue shale	3' 3"	238'
Hardrock	1'	239'
Blue shale	9'	248'
Black slate (Lower Rider)	2'	250'
Fire-clay	4'	254'
Blue shale (Lower coal)	21'	275'
Black slate	3'	278'
Fire-clay	1'	279'
Sandrock	1'	280'

The heavy sandstone we have referred to, it is easy to mistake for the basal sandstone or Parma sandstone, which indeed it may merge into near the margin of the basin, and I have referred it to the Parma sometimes. But more numerous records show that the sandstone zigzags through the formation as we have seen around Saginaw.

Coal has been found down to Elva and there may be some other pockets beyond. Near Millington on the old Blanchard farm 3 feet 7 inches of coal is reported at 190 feet. Around Unionville, near which there appears to be a dislocation and to the northwest of the Cass River, most wells show at least small seams of coal at various depths, but the records, while very numerous, are hardly near enough yet to connect the different coals with any precision, especially if there are faults.

Records in the southeast part of the county in Kingston show clearly that no coal is to be expected there.

Sanilac County.—This county has been reported by Dr. C. H. Gordon, Vol. VII, Part III.

The rocks appear to be entirely Eocarboniferous, and while fossil plants akin to those of the coal measures may be found, and indeed coaly streaks, there is little possibility of anything approaching a workable deposit of coal, and explorations for it are not worth while.

Kent County.—No coal has ever been struck in place in this county, so far as I know, but considering that we have at Grand Rapids beds almost identical with those at Bay Port, it would be natural to expect coal corresponding to the Sebewaing coal in the northeast part of the county heavily buried under drift, unless, as is probable, the bedrock surface dips to the northeast from Grand Rapids, somewhat following the dip of the limestone, for in a well at Saranac there is 227 feet of drift, and the bedrock surface is but 417 feet A. T. The coal series is very likely confined to the east bank of the valley thus made.

Ionia County.—The deep valley indicated by bedrock at 417 A. T. at Saranac probably runs nearly N. and S. into Barry county. Then the bedrock surface rises upon an escarpment of coal measure sandstones until it outcrops near Ionia and Grand Ledge.

On Sec. 26, Ionia township, T. 7 N., R. 6 E., Mr. Jas. Horrocks has put down two deep wells. Of the one put down in April, 1900, he gives the following record:

Surface and sandstone (Woodville?).....	75'	75'
Blue slate	20'	95'
Black slate	5'	100'
Coal	2' 2"	102' 2"
Fire-clay	102'	8"
Fine grit stone.....	8'	110' 8"
Blue slate	20'	130' 8"
Small seams, slate, coal, fire-clay, etc.....	43' 8"	174' 4"
Coal	0' 8"	175'
Small seams, slate, coal, fire-clay, etc.....	71'	246'
(Casing 200' 1").		
White sandrock, the Parma.....	87'	343'
Sandstone with a strong flow of water.		
Another well on the same section is 540 feet deep.		

A well for Henry Pierce in South Ionia is said to have gone through (the record is obviously very imperfect):

Iron ore (water)	3' 6"	at 60'
Coal, slaty	1' 2"	at 150'
Hard coal (? black slate or limestone).....	10'	160'
Soft coal	1' 2"	161'
Fire-clay	7'	168' 2"

Combining these with a well for M. W. Yeomans, Rominger's notes, and report of an old well by L. J. Lincoln, by his assistant, from memory, we get the following general idea of the strata:

Surface drift, up to 140 feet.

Sandstone, quarried, variegated red and white, probably Winchell's Woodville, replacing more or less normal coal series, up to 143 feet.

Shales and fire-clay with two or more seams of coal often over a foot thick, from 40 up to 175 feet.

Heavy white sandstones with artesian flows more than 100 feet thick, the Parma, down at 250 to 400 feet depth.

Red sandstone and very salt water at 700 to 800 feet (Marshall?).

Coal is reported a number of times near Ionia at about 200 feet depth.

Wells at Hubbardston 240 and 275 feet deep show that the surface deposits are nearly that thick, the bedrock being sandstone.

Clinton County.—A well in Lebanon township (8 N., R. 4 W.) shows 294 feet of drift here, with coal measure rocks beneath.

The most complete record is that of the St. Johns waterworks well given by L. J. Lincoln below, in which down to 608 feet neither coal nor black shale was mentioned. I suspect that part of the sandrock ? of this well may be really limestone or dolomite. Another well put down in 1901 has a quite different record. Some figures from it are given on the extreme right.

St. Johns water-works well, T. 7 N., R. 2 W. Record No. 2:

	Feet.	Feet.	New well.
Blue clay	19	19	
Pipe clay	12	31	
Clay and hardpan	61	92	
Stony and hardpan	19	111	
Granite boulder	21½	133	
Soft clay	10	123	
Gravel and hardpan.....	13	136	
Hardpan	5	141	152
Base of Drift or Pleistocene.....			
Red sandrock	5	146	172
Sandrock	20	166	
Gray sandrock	17	183	
Yellow sandrock	17	200	
To shale rock	14	214	
Shale rock	3	217	
Slate rock	26	243	
Blue sandrock	21	264	
Yellow sandrock	23	287	
Yellow hard and lighter.....	51	338	
Sandrock	6	344	
Hard blue sandrock	44	388	
Water rock	23	411	
Blue sand, harder.....	45	456	
Slate	12	468	375
Top of Parma sandstone—			
White sand	10	478	
Water rock sand	17	495	
Blue packed sand	22	517	
White water rock	10	527	525
Blue sand	13	540	
Perhaps beginning of Eocarboniferous lime- stone series, Upper Grand Rapids.			
Hard strata	10' 4"	541' 4"	
Blue sand to white.....	18'	559' 4"	
	3'	562' 4"	
Hard blue sandrock	27'	589' 4"	
Blue shale and sandrock.....	19'	608' 4"	
(Very hard.)			

The Kniffin well,* however, whose record is given in connection with analysis of the coal, is only three miles or so away, and shows two seams of coal, which appear to have been eroded away at St. Johns. These coals are very likely the Verne coals, and may connect with the coals worked at Grand Ledge and Corunna. In this case it is not at all impossible that the series of sandstones below, may, as at Ionia, split and make room for lower coals.

On the Brown farm near the southeast corner of Sec. 26, T. 5 N., R. 4 W., a coal shaft 52 feet deep, sunk about 1891, was a failure, largely owing to the water encountered, the section being:

Surface (till?)	12'	12'
Very porous sandrock	10'	22'
White sandrock and fire-clay.....	23'	45'
Slate	7'	52'
Coal		18" to 27"
Fire-clay		54'

Eastward the drift is thicker, on Sec. 24, T. 5 N., R. 1 W., 110 feet to rock.

The Pratt mine of the Grand Ledge district (which see) is just over the line in this county and is the only mine working in the county.

A good coal seam is said to have been found at 330 feet depth at Elsie, and the depth is not unlikely, for it is clear that going northeast the thickness of the coal-bearing series thickens from about 250 feet to 500 or more. The

St. Johns well may be entirely in the coal series, and certainly does not get down in the Michigan or Lower Grand Rapids group of gypsum, limestone, shales and salt water.

At Maple Rapids, about 640 feet A. T., much lower than St. Johns, we have the following record:

Hardpan	25	25
Blue clay	3	28
Stones	8	36
Blue clay	28	64
Hardpan	5	69
Sand with water	1	70
Blue clay	6	76
Sand	1	77
Brown clay	7	84
Gravel	2	86
Red sand (water)	82	168
Gray rock	14	182
Red sandstone (hematite)	2	184
Dark shale	31	215
Red shale	3	218
Soapstone	29	244
Light shale	17	261
Coal	2"	261' 2"
Light shale	33' 10"	295
White sandstone (water)	39	334

In a second test a 46 inch seam of coaly shale was struck at 325 feet depth on the farm of Hon. F. W. Redfern.

*Pages 105 and 115.

Shiawassee County.—Owosso and Corunna are one of the best known and steadiest coal districts, fully reported by Rominger in Vol. III. Additional information is given in the reports of C. D. Lawton, when mineral commissioner, and in Vol. V.

Most of the mining has been confined to the east central part of Caledonia township. (See description given with the analyses of the coals of the Owosso and Corunna Coal companies.) The two coals worked in this neighborhood not more than 80 feet down are probably the Verne coals, for there is coal found down to 216 feet, and, as Plate XII of Vol. V shows, there is at least 231 feet of coal measures, excluding the basal sandstone. The coal found at 180 feet depth at the D., G. H. & M. station at Milwaukee, though but six inches thick, may represent the Saginaw seam. W. F. Ward of the Owosso Coal Co. is said to have discovered three and one-half feet of good coal at 195 feet. Continued explorations have developed the coal northeast and north, while to the south of Corunna the wells show almost exclusively sandstones, e. g., at the schoolhouse one-half mile southwest of Corunna:

	Feet.	Feet.
Blue clay	12	12
Sand and gravel	35	27
Rest of surface deposits gray hardpan.....	63	90
Black slate	5	95
Sandstone	227+	322+

The series to the north contains more shale, which comes in, splitting up the sandstone as shown by comparing the record just given with Plate XII of Vol. V, or with the following:

Westhaven Township.

Sandy clay	51	51
Sandrock	4	55
Fire-clay	3	58
Gray rock	3	61
White sandrock	13' 2"	74' 2"
Coal	10"	75
Fire-clay	3	78
Gray rock	6	84
Coal	1' 3"	85' 3"
Fire-clay	2' 6"	87' 9"
Gray slate	2' 3"	90
Fire-clay	7	97
Slate	12' 3"	109' 3"
Coal (Lower Verne?)	3	112' 3"
Fire-clay	3' 9"	115
Gray slate	19	135
Black slate	3' 6"	138' 6"
Gray shale	14	152' 6"
Black slate	10	162' 6"
Gray rock	8	170' 6"
White sandrock	13	177' 6"
Black shale	13	190' 6"
White sandrock	10	200' 6"

Eight in the town of Corunna, Sec. 28, we have, according to Mr. W. F. Fowler:

	Court House.	Hotel.
Clay	16'	16'
Sand and gravel	4'	20'
Hardpan (till)	62'	82'
Fire-clay	4'	86'
Shale	10'	96'
Sandstone	144'+	240'+
With water of Sp. Gr.	1.001	1.003

The sandstone at the bottom is apparently continuous with that at 55'-135' in Plate XII, Vol. V, and apparently as we pass south the lower coal and shale seams thin out and the sandstones come together.

From Owosso north the depth of the drift is quite variable, as there are numerous channels in the rock surface. Eight in Owosso bedrock nearly outcrops and again is 100 feet deep. Kincaid's mine struck a gravel filled channel.

In the township north of New Haven, outcrops occur near Six-mile Creek, but only a few miles away it is very deep to bedrock. The channel probably goes northwest.

Off toward Venice and Hazelton townships (T. 7 and 8 N., R. 4 E.), coal continues in varying thickness, and explorations to a depth of 412 feet, have also been undertaken around the mouth of Six-mile creek, near the exposures of the upper coal beds which Rominger and Winchell described. This depth carries it into the basal Parma sandstone.*

The following record from Durand, where the general reports are that wells to rock are from 50 to 175 feet deep, say 120 feet deep and more, that McBride has a flowing well 140 feet deep, and that a well 400 feet deep got salt water is interesting, but difficult to interpret.

It seems likely that the bedrock is really at 109 feet instead of 238 feet, as given, and that the "water-bearing gravel, hardpan and stones" of the record is really a conglomerate. This is indicated by the fact that wells 178 feet deep yield a water with much less lime and more soda than water from shallower wells. Then the black shales beneath are those which have been noted in several other cases near the top of the Grand Rapids group, or more likely the unconformity at the base of the coal measures extends here down to the Marshall—compare the records around Flint.

DURAND WELL RECORD.

	a	b	a	b
Pleistocene.				
Surface clays.....	12'	12'	12'	12'
Quicksand.....	7'	7'	19'	19'
Gravel.....	4'	4'	23'	23'
Hardpan.....	18'	19'	41'	42'
Gravel.....	2'	2'	43'	44'
Hardpan.....	19'	20'	62'	64'
Gravel.....	1'	1'	63'	65'
Hardpan.....	15'	15'	78'	80'
Blue clay.....	10'	10'	88'	90'
Hardpan.....	10'	10'	98'	100'
Gravel.....	2'	2'	100'	102'
Hardpan.....	9'	7'	109'	109'
Brown shale.....	65'	34'	174'	143'
Parma or Napoleon.				
8 in. casing to 176 ft.				
Water bearing gravel.	4'	4'	178'	147'
If this is really under				
shale it must be a				
conglomerate.				
Hardpan and stones...	60'	62'	238'	209'
Iron casing 208 feet.				
Grand Rapids or Lower				
Marshall.				
6 in. casing to 267' 89'				
farther.				
Black shale.....	103'	107'	341'	316'
Well plugged at 332				
feet.				
Blue shale.....	2'	13'	343'	329'
Black shale.....	12'		355'	
Limestone.....	1'	1'	356'	330'
White shale.....	67'	69'	423'	399'
Green shale.....	10'	10'	433'	409'
White shale.....	54'	55'	487'	464'
Blue shale.....	20'	20'	507'	484'
Limestone.....	1'	1'	508'	485'
Blue shale.....	92'	95'	600'	580'
Limestone.....	5'	5'	605'	585'
White shale.....	14'	14'	619'	599'
Blue shale.....	24'	30'	643'	629'
Salt bearing sandstone	5'	5'	648'	634'
Blue shale.....			1'	653'

(a) Record from blue print furnished by R. R.
(b) " " files of Village Clerk. Total depth 636'; cost \$1800; yielded 4 gallons a minute of brine.

At Bennington, the well of Dr. Schickle is as follows:

	Feet.	Feet.
Loam	1	1
Red clay	10	61
Blue clay	50	66
Quicksand	5	86
Hardpan	20	100
Shale	14	122
Sandrock	22	

*Compare Pl. XLV of Vol. V.

Genesee County.—The coal beds cross the northwest corner. The coal beds reported beneath Flint may be insignificant, possibly in the Grand Rapids series, though I think that it is absent here, but the following record is clearly well within the coal measures, and is authenticated by samples:

Flushing, 300 feet west of Flint River, on N. W. ¼ of Sec. 15, T. 8 N., R. 5 E. Drillers, Deland and Robinson. Reported by E. G. Goodell.

Sept. 8 and Nov. 14, 1898.

	Feet.	Feet.
Surface sand	15	15
Clay with streaks of gravel.....	47	47
Quicksand	2	49
Hardpan clay (till).....	2	51
"Slate" shale	2	53
Slate	15	68
"Slate"	9	77
Sandrock	9	86
Black slate (bituminous represents a coal horizon probably).....	1	87
Fire-clay	3	90
Sandrock	4½	94½
"Slate" shale	4	98½
Dark shale	8¾	107¼
Shale	20¾	127½
Coal and black soft slate. This coal is probably lower than the Verne coal, and in varying thickness is quite persistent in the region	¾	128
Sandrock	3	131
Shale	21	155
Hard shale	27	182
Hard shale	28	210
Slate with pyrite	6	216

Coal has also been dug in the shale pits of the Saginaw Clay Mfg Co., near the S. W. corner of Sec. 22,* and is also said to outcrop on the river bank near the northeast corner of Sec. 4, of the same township. In the township north of Montrose a coal mine was started by a slope at Elk, but failed. Similar strata occur on Sec. 26, and appear to belong near the horizon of the Verne coals.

The seams of coal so far as at present explored, appear to be persistent but of varying thickness.

A good seam is said to have been discovered by Martin G. Hope at East Thetford to the northeast, 140 feet deep.

At the residence of F. E. Holliday, Eighth St., Flint, eight inches of coal are said to have been found at 90 feet.

Eight feet of coal were reported at 87 feet deep on the place of Mrs. Mary Conger, Sec. 3, and nine feet in a later well, but the wells were for water and the presumption is that most of it was black shale.

It appears probable that in this county the coal is confined to the northwest of a line from Fostoria to Durand and that the coal probably occurs at less than 250 feet depth.

The record of the Oak Grove mineral well, Sec. 7, T. 7 N., R. 7 E., is reported as follows:

Casing	39'	39'
Sandstone	79'	118'
Coal	4' 4"	122' 4"
Sandrock	15'	137' 4"
Slate	60' 9"	198' 1"
Sandrock	67' 6"	265' 7"

*See Part I of this volume, and also the analysis of the same.

Barry County.—There has been quite a little talk of coal in this county, and the Thornapple Coal and Oil Co. formed. The coal appears, however, to be all drift coal. For instance, about 800 paces N., 1600 W., in Sec. 6, T. 2 N., R. 7 W., in the valley of High Bank creek the following section was exposed:

	Feet.	Feet.
Till and beneath it stratified clay.....	15	15
Quicksand	20	35

with fragments of coal quite abundant at the bottom. Underneath is clay and then quicksand is said to recur, and the occurrence of clay capping the hills over sand is quite common.

The abundance of coal in the drift indicates that coal seams are not far off, but the Nashville water-works wells are said to go through about 100 feet of sand and gravel, 40 feet of clay, and the balance 115 to 125 feet in limestone rock, though another less reliable report says that they go through sandrock down to 300 feet. Bedrock here then will be the Eocarboniferous (Upper Grand Rapids) limestone, but there may be a chance for coal to the north.

Eaton County.—At the south side of the county the record of importance to add is the following of a mineral well by L. J. Lincoln at Eaton Rapids. The first 116 feet are undoubtedly in the coal measures, and the well seems to pass into the Parma or Grand Rapids group below. Lincoln's records rarely show coal, and the unintelligible P. K. slate (poor coal) appears in a place where older records report coal. Six miles southeast of Eaton Rapids, good coal is said to have been met.

T. 1 N., R. 3 W., Eaton Rapids:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Old gravel	22	22
Sand gravel	5	27
Shale rock	10	37
Shale rock	30	67
P. K. slate (?).....	28	95
Fire-clay	7	102
Sand and (?).....	14	116
Water sand	43	159
Gray rock	20	179
Lime rock	2	181
Mineral rock	3	184
Sandrock	10	194
Water rock	11	205
	1	206

Farther north, close to the county line a core drill proved the sandstone on Van Osdall's farm N. E. ¼ of Sec. 25, T. 3 N., R. 3 E., where a quarry was projected. For 75 feet it was all sandstone. From 14 to 39 feet the samples show coarse white sandstone. Above this are slaty streaks, and at 7 to 9 feet are brown blotches, apparently pebbles of FeCO₃, such as occur in a sandstone over the coal at Williamston. The sandstone outcrops in the river near by.

About half-way down the river to Lansing, near Milletts, there have been explorations from an early date. A shaft for coal on the farm of Mr. Minie, Sec. 35, was put down in 1858 to 1859.

A section is given by Winchell, 1860 report, p. 124; see also Rominger III, p. 130, as follows:

Surface	5'	5'
Fire-clay, soft	2' 8"	7' 8"
Coal	2' 3"	9' 11"
Clay somewhat bituminous	4' 3"	14' 2"
Coal	1' 11"	16'
Fire-clay, white and hard	5' 8"	21' 9"
Argillaceous shale	16' 2"	36' 11"
Coal	0' 8"	37' 7"
Argillaceous shale with some pyrite.....	12'	49' 7"
Sandrock	4' 2"	53' 9"
Coal	4' 1"	56' 10"

On the other hand, a well on the farm of W. E. Locke on the same section 35, T. 4 N., R. 3 W., drilled in 1899 for Mr. W. O. Smith (Alt. 875) is reported as follows:

Drift	Feet.	Feet.
Fire-clay	2	2
Shale	15	31
Coal	2	33
Shale?	17	50

Some Ohio people are also said to have drilled here.

Two reasons for abandoning the early explorations are given—that there was not enough roof, and that it was not thick enough to pay. Both may be correct, the one applying to the coal less than 20 feet down, the other to the lower coals, though if there were really four feet of coal at 56 feet it is hard to understand why it could not be successfully worked.

Making allowance for exaggeration, however, it still appears that in the first 60 feet are two or three coals, and only four or five miles away, in the next county, coal is found near the surface in some of the Lansing wells, and is said to have outcropped beneath some blue shale which lay below the sandstone quarry in the rapids of the Grand River, obliterated by the dam at North Lansing, a mile and a half up stream from Lansing. Within the county we find at Grand Ledge a similar section, where coal has been worked since 1839. The best section is exposed in the clay pits of the American (Grand Ledge) Sewer Pipe Co., about 1100 paces north, 500 west of the southeast corner of Sec. 3, T. 4 N., R. 4 W., as follows:

	Feet.	Feet.
Decayed sandstone	3	
Shale with streaks of FeCO ₃	4	7
Black shale, coaly (Upper Rider).....	1	8
White shale, best sewer pipe clay, bounding line with next formation below undulating as if this is an alternation of the layer below (See analysis in Vol. VIII, Part I.)	2	10
Blue shale with <i>Sphenophyllum cuneifolium</i> and nodules of FeCO ₃ , with ZnS and FeS ₂	4	14

Black shale passing at east end into five inches of coal and thickening in Boyle's shaft, not far off into from 18 inches to 24 inches, apparently visible as a thin seam 4 inches or so thick, 12 feet above the main workings of C. Hodge, which are in a ravine just west.

This is also said to be the coal mined in the Pratt mine just over the county line in Clinton county on the west bank of Grand River where it is at times 30 inches thick. Harder than, and not so brittle as the next lower seam, with greater irregularity in thickness apparently. The black shale directly above contains a delicate compressed lamellibranch (cp. *Anthracosia* or *Macrodon carbonaria*).

The coal was also mined some years ago at a profit in a shaft by Irving Jenkins, close to the Boyle shaft. Farther southwest the whole series seem to pass into sandstone, and in another shaft the coal was found to be so split up as to be unworkable.

	Feet.	Feet.
Upper Verne	1	15
Under this coal come black and white flaking sandstones (Ashley calls them fake) sometimes quite massive, as at Hodges' drift and varying much in thickness,—usually from 10 to 20 feet thick.....	20	35
Next we have a lower seam of coal, Analysis (E.) more uniform in thickness, more brittle than the upper coal, and known locally as the 18 inch or sandstone coal, quite persistent, worked by Arnold and R. P. Wilkin-son (Lower Verne).....	1' 6"	36' 6"
Below this comes the sandstone again.		

The lithological character of the section is quite variable, as well as the thickness of the different members. In Boyle's mine in one place the two coals approach so near that in taking up the foot of the upper coal the lower is exposed. In fact, in the bluff of the river to the east of the clay pit they appear within 7 feet of each other, the upper only 9" thick, the lower 15".

In a clay pit on the N. W. ¼ of Sec. 11 under a heavy cross-bedded sandstone 15 feet thick comes a few inches of shales, from which most of the specimens come on which the correlation with the Mercer group was based by White.*

Then about two feet of coal rolling and dipping in one place to N., in another 10° to 15° to E.

Then 3 feet of fire-clay and shale. The coal here I take to be the upper seam.

One or the other of the coals may be traced up the river through the town, having been worked according to reports under the grist mill (upper coal). In the Island House (Mudge) well 18 inches of coal is said to have been found near the top, though Rominger reports one at 65 feet. Below for 100 feet or more and in a deeper well put down by Dr. Ball, near the river and the east line of Sec. 11, T. 4 N., R. 4 W., only sandstone is reported. From the general succession as well as the fossils associated and the character of the coals, we seem to have here an Upper Rider, the Upper Verne and the Lower Verne coals. The basal series of sandstones do not appear to be split by the coals of the Saginaw series.

The coals exposed in the deep cut of Grand River probably extend clear across the county, though covered with a heavy layer of drift, through which little or no drilling has been done. When we go south, however, into the valley of the Thornapple, exposures occur

around Chester of a coal seam, at most three feet thick, as described by Rominger.†

Samples from a recent boring near Carlisle on the S. E. ¼ of Sec. 24, T. 2 N., R. 6 W., are as follows:

Surface, blue clay broken at the bottom.....	39'	39'
Black shale with thin seams of coal,—a coal horizon	11'	50'
White shale, under clay.....	3'	53'
Dark shale with some FeCO ₃	2' 6"	55' 6"
Black and white shale	2' 6"	58'
Blue shale	1' 10"	58' 10"
White sandstone	1' 2"	60'
Black and white shale	6' 6"	66' 6"

We have coal measures, obviously, and it would seem worth while to go somewhat deeper, though the record of the deep well at Charlotte is not encouraging.

In the southwest part of the county around Bellevue the Eocarboniferous limestone outcrops and no coal is to be expected, and it is probable that the productive coal measures of the county are rather thin everywhere, with no indications of coal seams below the Verne (Grand Ledge) seams, except perhaps in the extreme northeast.

*Page 44.

†Vol. III, p. 131.

Ingham County.—Many records from the neighborhood of Williamston are given in Vol. III of our reports.*

In a general way it is said that there is a 44 inch bed of coal, outcropping, or but a few (13) feet below surface, so having no roof. About 48 feet below the surface is a second seam.

Rominger summarizes them as follows: "The above experiments show a uniform distribution of a coal seam about 3 feet in thickness over this whole district. Its position is often too superficial, without a proper roof, for advantageous mining. In nearly all the borings two seams of coal are found, of which the upper one is generally too narrow to be of practical value. The two seams are separated by from 15 to 20 feet of intermediate beds."

One of the exposures of the coal measure shales, etc., is shown on the farm of C. M. Phillips, Sec. 28, T. 4 N., R. 1 E., near which were some of the earliest coal diggings. Nodules of FeCO₃ are common, and the dump of the abandoned coal mine shows numerous fragments of a conglomerate with a white sandstone matrix and numerous pebbles of FeCO₃.

The two coal seams to which Rominger refers I take to be the Verne seams, and they are associated with black shales containing similar marine animals.

The following records, which I owe to Mr. W. T. Chappell, show that the Saginaw seam exists below.† The J. H. Somers Co. also found some coal down at 249 feet.

Records for W. T. Chappell, by O. A. Shadbolt, near Williamston, Ingham county:

No. 1, S. W. ¼, Sec. 34, T. 4 N., R. 1 E.

Yellow sand and clay.....	12'	12'
Fine sand.....	8'	20'
Blue clay.....	25'	45'
Hardpan.....	21'	66'
Blue shale.....	23'	89'
Fire-clay.....	10' 8"	99' 8"
Black slate.....	8'	107' 8"
Coal (Upper Verne?).....	8'	108'
Black slate.....	8'	116'
Gray slate.....	7'	123'
Black slate.....	8'	131'
Fire-clay.....	3'	134'
Black slate.....	4'	138'
Fire-clay.....	7'	145'
Black slate.....	5'	150'
Coal (Lower Verne?).....	6'	150' 6"
Sandy shale.....	6'	156' 6"
Black slate.....	7'	163' 6"
Sandy shale.....	8'	171' 6"
Black slate.....	1' 6"	173'
Gray slate.....	24'	197'
Black slate.....	4'	201'
Sandy shale.....	3'	204'
Black slate, strong.....	9'	213'
Coal (Saginaw?).....	2' 6"	215' 6"
Fire-clay.....	6'	221' 6"
Gray slate.....	43'	264' 6"
Black slate.....	10'	274' 6"
Gray slate.....	14'	288' 6"
Black slate.....	2' 6"	291'
Hard rock.....	2' 6"	293' 6"
Black slate.....	11'	304' 6"
Sandy shale.....	2' 6"	307'
Sandrock.....	3'	310'

No. 2, N. E. ¼, Sec. 3, T. 3 N., R. 1 E. About 40' lower than No. 1, June 3, '99.

Sand.....	12'	12'
Clay.....	6'	18'
Sand.....	2'	20'
Hardpan.....	7'	27'
Black slate.....	3'	30'
Fire-clay.....	22'	52'
Soft black slate.....	7'	59'
Coal (Upper Verne?).....	1'	60'
Fire-clay.....	21'	81'
Gray slate.....	8'	89'
Black slate.....	20'	115'
Coal (Lower Verne?).....	6'	115' 6"
Fire-clay.....	9'	124' 6"
Sandy strata.....	29'	153' 6"
Gray slate.....	1' 6"	155'
Sandrock.....	2'	157'
Sandy shale.....	8'	165'
Sandrock.....	11'	176'
Gray shale.....	4'	180'
Sandrock.....	3' 6"	183' 6"
Sandy shale.....	1'	189' 6"
Sandy fire-clay.....	1' 6"	191'
Gray slate.....	35'	226'
Sandy shale.....	13'	239'
Gray slate.....	7'	246'
Black slate.....	11'	257'
Coal (Saginaw?).....	1' 4"	258' 4"
Fire-clay.....	3'	261'
Sandrock.....	4' 6"	265' 10"

No. 3, N. W. ¼ of Sec. 33, T. 4 N., R. 2 E. Leasia farm, 160 rods W. of N. W. of No. 1 and perhaps 10' higher.

Clay.....	12'	12'
Sand.....	13'	25'
Clay.....	25'	50'
Hardpan.....	8'	58'
Clay.....	12'	70'
Hardpan.....	5'	75'
Sandrock.....	15'	90'
Black shale.....	10'	100'
Coal (U. Verne?).....	1' 4"	101' 4"
Fire-clay.....	2'	103' 4"
Gray shale.....	4'	107' 4"
Black shale.....	4'	111' 4"
Gray slate.....	2'	113' 4"
Fire-clay.....	2'	115' 4"
Black slate.....	6'	121' 4"
Sandy fire-clay.....	6'	127' 4"
Gray slate.....	5'	132' 4"
Fire-clay.....	2'	134' 4"
Gray slate.....	13'	147' 4"
Black slate.....	14'	161' 4"
Sandrock.....	2'	163' 4"
Fire-clay.....	3'	165' 4"
Coal.....	6"	165' 10"
Fire-clay.....	4' 6"	170' 4"
Black slate.....	6"	170' 10"
Coal.....	6"	171' 4"
Fire-clay.....	8'	177' 4"
Sandy shale.....	40'	217' 4"
Black slate.....	3'	220' 4"
Sandrock.....	10'	230' 4"

*Part I, pp. 130, 135, 136. See also Lansing, "Exposition concerning Mineral coal in Michigan," Detroit, 1854.

†See also Michigan Miner, Vol. 3, No. 7, p. 16, June 1, 1901.

These wells of Shadbolt may be compared with the following one of L. J. Lincoln, who, it will be noticed, probably did not distinguish the coal from the slate. We see that the coal measures continue down anyway to 362 feet, and the black slate from 323 to 345 feet may very easily be the same black, coal-bearing horizon that was struck in No. 1 at 289' to 305'.

N. W. corner, Sec. 33, T. 4 N., R 1 W., Meridian township:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Old well	23	23
Soft clay	17	50
Clay and hardpan	40	90
Beginning of coal measures—		
Shale	15	105
Slate	95	200
Slate to sand	20	220
Sand and water	27	247
Slate	34	281
Shale	22	303
Black slate	20	323
Soapstone	22	345
Fire-clay	17	362
Light slate	35	397
Beginning of Parma sandstone? and transition to Eocarboniferous limestone—	15	412
Light sandrock	16	428
Lime rock	11	439
Sand	10	449
Fine sand	7	456
Fine sand	24	480
White sand	19	499
Sand to hard rock	10	509
Hard lime	5	514

Coming about an equal distance northwest to the Agricultural College, on Sec. 18, T. 4 N., R. 2 W., we have the old well put down by L. J. Lincoln in 1887, of which there were 15 bottles of samples taken—and 13 now left at the Agricultural College. By their means we may correct Lincoln's log and obtain the following record:

RECORD.		
Quicksand	11	11
Clay (10-20)	9	20*
Hardpan, i. e., till, dark clay and sand.....	17	37*
Black shale	3	40*
(Very dark with bits of coal, other wells near by are said to have struck coal at this level).		
Fire-clay	2	42
Fire-clay and shale	42	84*
(50-76, light clay shale).		
Sandrock	118	202*
(84-165, light).*		
(152-162, sandy clay with dark bits).*		
(162-180, white sand with coal 10% or so).*		
(180-187, white sand, coarse, with coal).*		
(187-218) fine sand with iron rust, probably representing pyrite and black specks).		
Shale (?)	33	235
Sandrock	25	260*
(265-308, very fine, blue sandrock).		
Shale	40	304*
(265-308, very fine, blue sandrock)		
Sandrock	29	333*
(308-329, white sand).*		
Shale	16	349
Sand	2	351

*Represented by samples; descriptions in parentheses are from samples and not from Lincoln's records.

In Carpenter's paper on the use of this water as a boiler water the depth is given as 265 feet. (Trans. Am. Soc. Mich. Engineers, XI, p. 239), probably a misprint for 365 feet. Various reports made the well from 343 feet to 470 feet deep. Originally, however, it seems to have been 365 feet deep, though the report of the state board makes it 343 feet deep, cost \$1,000.

Another well was put down near by in 1899, by Elmer E. Strope of Mason, Mich., of which the State Geological Survey have a set of samples.

Sec. 18, T. 4 N., R. 1 W., depth (p. 17 of 1900 report) 345', cost \$700.00:

Sand, fine.....	8'	Comparison with other wells.
Gravel, fine.....	21'	
Brown smooth clay.....	2'	
Dark blue shale.....	45'	
First water here.....	37'	No. 1, 37-84 with coal.
Fine grained white sandstone.....	82'	
Coarse sandstone, white.....	125'	No. 1, 260.
Flow of water.....	35'	
Sandy shale.....	190'	No. 1, 260-304.
Coarse white sandstone, conglomerate at 185 feet.....	12'	
Yellow sandstone.....	172'	No. 1, 260-304.
Sandstone and coal.....	44'	
Coarse pyrite sandstone.....	216'	No. 1, 260-304.
Dark sandy shale.....	14'	
Sandstone and siderite, very hard.....	220'	No. 1, 260-304.
Sandstone and coal.....	9'	
(Good clean samples, said to be a few inches thick) at 280 feet.	10'	No. 1, 260-304.
Shale, or fire-clay.....	3'	
Smooth shale.....	280'	No. 1, 260-304.
Water sandstone?.....	39'	

In these two wells a big body of sandstone with some streaks of coal in it, separates a lower and upper body of shales.

Passing two miles and a half farther to the industrial School in the E. ½ of the N. W. ¼ of Sec. 15, which stands about 20 feet higher, we find the record:

	Feet.	Feet.
Clay and gravel.....	36	36
Sand and gravel.....	5	41
Sandy hardpan	4	45
Lake sand and gravel.....	37	84
Clay, sand and gravel.....	16	100
Lake sand and gravel.....	1	101
Soft sandrock	3	104
Hard fire-clay	4	108
Soft white sandrock	13	121
Soft sandy fire-clay.....	15	136
Hard sandrock	119	255
Winchell says from 101 to 255 is sandstone "first water."		
Hard fire-clay alternating with beds of sand-rock variable in color from whitish to blue..	64	319
Cherty lime	1	320
Gray lime	4	324
Sandy fire-clay mixed with seams of hard rock	51	375
Soft sandrock	37	412
Hard gray limestone	2	414
Soft white sandrock	15	429
Blue limestone	1	430
White fire-clay	1	431
Sandrock	4	435
Fire-clay with iron pyrites.....	50	485
Soft sandrock	5	490
Blue limestone	16'	506' 6"

The difference in thickness of drift corresponds practically to the difference in elevation of this and the Agricultural College wells, and we plunge at once into a sandy series which culminates about 255' down. This record shows no coal, but King and Wigant say they found at the North Lansing railway station of the Pere Marquette:

	Feet.	Feet.
Surface with 14 feet of gravel.....	55	55
Sandrock with 6 inches of coal at 62 feet.....	18	73

Coal is also reported from a number of wells near the School for the Blind, e. g., at Christopher's, 434 Willow St., in the bed of the river, and at 430 Willow St. there is said to be 3 feet of coal; at Shadoin's, 612 Saginaw St., 5 feet thick, the section being as follows:

	Feet.	Feet.
Clay	65	65
"Soaprock" shale	14	79
Coal	5	84
Sandrock	26	110

at Watson's, 606 Saginaw St., 1 foot thick. Hon. J. Robson, 321 Walnut St., is said to have found 4 feet of coal in his well.

At the corner of Pine and Kilborn Sts. there is said to be

	Feet.
Casing	58
Black rock	2
Coal	5

At 501 Pine St., H. E. Cadwell, there is said to be 4 feet of coal at 75 feet. So that the upper coal horizons must be fairly persistent near the bedrock surface, perhaps too near to work.

Still, the coal is not continuous, as we see from a record at 318 Jefferson Ave.

	Feet.	Feet.
Red clay	16	16
Blue clay free from stones	10	26
Blue quicksand, water rises to 12 feet from the surface	6	32
Water sand	8	40
Blue clay or soaprock	25	65
Probably sandrock	11	76

When we turn to the southeastern part of Lansing we find less trace of coal.

Lincoln's record of the Condensed Milk Company's well is as follows:

	Feet.	Feet.
Sand and gravel	16	16
Sandrock	15	31
Fine sand	5	40
Water sandrock to shale	28	68
Slate	10	78
Light slate (probably the fire-clay below the coal horizon) and sand.....	17	95
Fine sandrock	22	117
White sandrock	21	138
Light sandrock	20	147
White sandrock	17	164
Gray sandrock	18	183
Fine sandrock	5	198

This is not far from the Industrial School, but a good deal lower, as is shown by the thinness of the drift, for the rock surface appears to be pretty flat. In fact, in the abutments of the Michigan Avenue bridge, across the Grand River, near this well, the sandstone was struck and slabs of it are preserved at the Agricultural College. Close to the bridge, too, are the water-works wells—those which are used meeting rock at about 36 to 46 feet and ranging mainly 150 to 160 feet deep. But there is one deep one at the S. W. corner of the lot, whose record, Feb. 17, 1896, from the State Republican, is as follows:

	Feet.	Feet.
Surface to rock	46	46
First eight feet soft, porous, coarse sand-rock	30	76
Hard clay	2	78
Finest sandrock, plenty of water.....	100	178
Fire-clay	2	180
Blue sandrock	20	200
Yellowish sandrock, plenty of water.....	30	230
Fire-clay	2	232
Grayish rock	30	262

Gold particles were said to be found, probably pyrite or bronzy mica.

	Feet.	Feet.
Fire-clay	15	277

At 275 feet was a rock "as hard as flint, and the sand pump yielded a metal that resembled gold," i. e., pyrite.

	Feet.	Feet.
White sandstone porous.....	25	302
"Granite" stone, very hard.....	25	327
Hard white rock, with big flow of water rising within 5 feet 9 inches of surface, and much above the water.....	13	340

Probably through this part of the town the sandrock is the surface rock, as indicated by the following wells:

Lantz' well at the laundry, 120 feet deep, 60 feet to 80 feet to bedrock, Piatt's, behind the Downey House, 58 feet to rock and white sandstone down to 112 feet (1901).

The Downey House well recorded by Winchell* thus:

	Feet.	Feet.
Sand	4	4
Light blue clay	10	14
Sand and clay	4	18
Sand and gravel	37	55
Sandstone	7	62

continued to 500 feet, according to Rominger, or 740 feet, some say, when it became too mineral in taste and is now plugged at about 70 feet. The Hollister Block well is about 150 feet deep. The city water-works test well, now flowing close to the junction of the Cedar and Grand rivers, on Hazel street, which Mr. Stephenson tells me was mainly clean white sandrock, was 340 feet deep, and six blocks west, at the corner of Isaac and Chestnut streets, is a similar flowing well 365 feet deep.

*Am. Ass. Adv. Sci., 1875, B., p. 31.

Southwest of Lansing, in the bed of the Grand River, was a sandstone quarry, and Mr. George H. Pratt informs me that in quarrying under the sandstone a shale with coal was exposed.

Mr. Lincoln also put down a large number of wells around Mason. As we have seen, lie does not distinguish the coal from black slate, but from the following records we see that there are one or two coal horizons in the first hundred or hundred and fifty feet,* and one considerably lower. Somewhat below 300 feet we pass into the Eocarboniferous limestone series, so that the strata lie as deep here as 10 miles north.

Wherever black slate, brittle slate and shale appear in his records there may be more or less coal.

A heavy sandstone quite frequently separates the upper coal horizons which we may correlate with the Verne, from the lower, which we are inclined to correlate with the Saginaw as we did at Williamston, with which it seems to connect.

There is no close parallelism but merely an epoch of some- what more disturbed condition and coarser sediment which we seem also to trace through to the north.

T. 2 N., R. 1 W., S. W. part Section 3. Record No. 20:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Sandrock	13	13
Sand and water-pack sand	22	35
Blue sand and gravel	5	40
Shale	7	47
Shale and hard spots	5	52
First hard rock at.....		52
Shale	6	58
Soft sandrock	2	60
Water and sandrock	5	65
Water and hard rock	2	67

N. E. corner of N. E. quarter of section 8, block 4, Mason, Vevay township:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Slate	13	22
Light slate	19	35
Slate	21	54
Slate to sandrock	45	75
Gray sandrock	29	104
White sandrock	30	134
Sand to slate	18	152
Black slate	29	181
Fire-clay	15	196
Light slate	13	209
Lime and slate	8	217
Soft lime	6	223
Light slate	30	253
Hard rock	4	257

*See Rominger, Vol. III, Part I, p. 130.

Mason City water-works, on city lots:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Hardpan and clay	15	15
Gravel and sand	5	20
Black shale	3	23
Light shale	15	38
Water sandrock	26	64
Water sandrock	34	98
Hard sandrock	22	120
Softer sandrock	10	130
To slate	11	141

Mason City water-works well, south of plant, No. 1: Record No. 5.

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
(Old well?)		69
Fine sand	14	81
Sand to hard rock	4	85
Gray sandrock	6	91
White sandrock	20	111
Sandrock	10	121
Blue sandrock	11	132
White sandrock	7	139

Mason City water-works well, N. E. part block 43,
Record No. 7: T. 2 N., R. 1 W.

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Gravel	2	3
Water gravel	1	6
Gravel and sand	14	20
Hardpan	8	28
Hardpan and shale	4	32
Fire-clay	2	34
Black slate or shale, coal horizon	10	44
Lighter shale	10	54
Hard rocks	2	56
Sand and water	31	87
Sandrock	13	100
Slate	12	112
Sandrock	6	118
Light shale	6	124
Light sandrock	5	129
Shale	2	131

Mason City water-works well, Lot 11, block 15; Record
No. 8:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Shale rock	11	14
Slate and sandrock	22	25
Sandrock	22	47
		69

Record No. 9:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Clay and sand	6	6
Sand, clay and gravel	25	31
Hard rock	3	34
Sandrock	7	41
White rock	14	55
Slate and sandrock	11	66
White sandrock	24	90
Gray sandrock	10	100
Sandrock	31	131
Fine sandrock	19	150
To slate	5	155

Mason City water-works, city lots, Record No. 10:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Sand, gravel and hardpan	9	5
Shale and slate	10	14
Light slate	26	24
Sandrock	15	50
Water rock	2	65
		67

Record No. 11:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Sand and gravel	9	3
Shale	5	12
Sand slate	10	22
Slate	12	35
Sandrock	19	47
Fine sandrock	33	66
White sandrock	60	99
Blue sand and putty (soft clay)	13	159
		172

S. W. corner block 1:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Old well	70	70
Sandrock	35	105
Sand to hard rock	17	122
Very hard sandrock	4	126
Sandrock	68	194

N. W. corner block 12, Mason:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
No record	36	36
Sand and gravel	18	54
Shale and hard rock	7	61
Black slate	8	69
Light slate	36	105
Sandrock	27	132
Slate	18	212
Black slate	21	233
Black slate to sandy spots	13	246
Slate	28	274
Light slate	14	288
Fire-clay	32	321
Hard rock	6	327
Soft to hard rock	13	340
Water sandrock	45	385

T. 2 N., R. 1 W. N. E. part block 52, city:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Black shale	33	20
Light shale	17	53
Sand and water rock	20	70
Slate	14	90
Sand and water	61	104
Sandrock	31	165
Blue sand	6	196
Sandrock	10	202
Light slate	8	212
Light slate to fire-clay	10	220
Fire-clay	9	230
Fire-clay to slate	10	239
Slate	8	249
Slate to sand	3	257
Sand and water	8	260
Light slate	3	268
Fire-clay	12	271
Light slate	6	283
Dark slate	5	289
Light slate	6	294
Fire-clay with hard spots	17	300
Water rock	49	317
Firm sandrock	20	366
Limerock	5	386
		391

T. 2 N., R. 1 W. S. W. part of block No. 7, Steel and
Holt's Addition:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Sand	23	28
Sand and hardpan	10	38
Black slate	15	53
Slate rock	7	60
Sand and slate	1/2	60 1/2
Fine sand and slate	50	110 1/2
Blue	23	133 1/2
Water rock	27	160 1/2

Mason City water-works well, N. E. part block 43:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Gravel	2	5
Water gravel	1	6
Gravel and sand	14	20
Hardpan	8	28
Hardpan and shale	4	32
Fire-clay	2	34
Black slate or shale	10	44
Lighter slate	10	54
Hard rock	2	56
Sand and water	31	87
Sandrock	13	100
Slate	12	112
Sandrock	6	118
Light shale	6	124
Light sandrock	5	129
Shale	2	131

N. W. corner, block 18, city, record No. 21:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
To gravel and sand	2	8
Gravel and sand	2	10
Blue clay	8	18
Hardpan	8	26
Hard limerock	8	34
Slate rock	10	44
Dark flakes	2	46
Hard limerock	44	167
Blue sandrock	10	177
Sandrock	11	188
Fine sandrock	14	202
Hard sandrock	3	205

Block 24, lot 3, Mason, Record No. 27:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
To gravel	21	6
Clay	13	27
Blue clay	10	40
Fire-clay and light slate	24	50
Hard sandrock	16	74
Fine sandrock	14	90
Sand and water rock	9	104
		113

T. 2 N., R. 1 W. E. half of Sec. 9, Vevay township:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Clay	10	3
Hardpan and gravel	18	13
To shale	2	31
Shale	2	33
Shale and slate	12	35
Slate	82	47
Sand and slate	69	129
To shale	13	198
Black shale	18	211
Light shale to hard limerock	15	229
Limerock	3	244
Light clay	23	247
Fire-clay to slate	15	270
Shale	15	285
Shale	27	300
Top of <i>Encarboniferous</i> (?)		327
Sand and hard rock	19	356
Sandrock	45	401

T. 2 N., R. 1 W., S. W. corner Sec. 14:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Clay and hardpan	15	20
White clay and lumps of coal.....	4	24
White clay and sandstone	15	39
Light shale	23	62
Dark slate	10	72
Black shale	2	74
Slate and coal	3	77
Light slate	12	89
Slate and lime	6	95
Light slate	3	98
Fire-clay	2	100
Black slate, brittle.....	5	105
Sandrock	1	106
Light slate	10	116

N. E. corner Sec. 20, Vevay township, Record No. 32:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Old well		42
Sand to gravel	21	63
Hardpan and sand	3	66
To rock	36	102
Hardpan	8	110
Slate	9	119
Light slate	9	128
Light slate and sand	17	145
Hard sandrock	8	153
Water rock	5	158
Sandrock	13	171

T. 2 N., R. 1 W., S. W. corner N. W. quarter Sec. 22:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Old well		62
Black slate	21	83
Black slate to sand	20	143
Sand to slate	20	163
Very hard rock	29	192
Blue sand	2	194
Fire-clay	13	207
Light slate	15	222
Dark slate	13	235
Light and dark slate	12	247
Light and dark slate	18	265
Light and dark slate	11	276
Fire-clay	10	286
Light shale	10	296
Light slate	9	305
Light shale	9	314
Eocarboniferous limestone—		
Hard lime	4	318
Hard rock	16	334
Sand and lime	11	345
Sand and water rock	22	367
Very hard	1½	368
Lime	4	372
Sand and water	11½	384
Water	19	403
Water rock	6	409

S. W. corner Section 27 (Eden), Vevay township, Record No. 33:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Old well		9
Clay	18	27
Hardpan	11	38
Sand and water rock	14	52
Pure clay and shale	8	60
Sand	19	79
Hard sandrock	7	86
Water rock	2	88
Water rock	16	104

T. 2 N., R. 2 W.; N. E. corner of S. E. quarter, Section 23, Aurelius township, Record No. 26:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Old well		33
Hardpan and rock	5	38
Slate and sand (stones).....	15	53
Soap stone and clay	7	60
Slate	23	83
Sand (stone)	12	95
Sand and sand (stone)	30	125
Sand (stone) and shale	9½	134½

Coal is reported from T. 1 N., R. 2 W.

Coal has been found on the farm of J. R. Potter, Sec. 6, T. 2 N., R. 2 E., by J. McDowell at a depth of 25 feet. It is said to be three feet thick. There is no doubt that practically the whole of the county is underlain by the coal measures.

Livingston County.—The coal measures may cross the west part of this county, but the following record, by L. J. Lincoln, at Howell, can be best interpreted by supposing that the shales are in the same series as at Durand, and

that perhaps some of the overlying sandstone or conglomerate was not distinguishable from the hardpan above. The bedrock first struck is probably the conglomerate at the base of the coal series, and the shales below are Lower Marshall and Coldwater.

Howell Condensed Milk Company's well, T. 3 N., R. 4 E.:

Character.	Thickness of stratum. Feet.	Total Depth. Feet.
Clay	5	30
Clay and gravel	19	49
Marl and sand	8	62
Pack sand	20	82
Pack sand to hardpan.....	17	99
Stony	14	113
Stony hardpan	5	118
Clay and hardpan	1	119
Hardpan	5	124
Quartz rock	48	172
Hard rock	4	174
Sandy	4	178
Sand and water	1	179
Fire-clay	19	198
Light shale	11	209
Sand and slate	18	227
Fine sand	5	232
Light shale	12	244
Light shale	16	260
Soapstone	19	279
Sand	10	289
Light shale	3	292
Black slate and brown shale.....	43	335
Brown shale, harder	79	414
Light shale	66	480
Slate	60	540
	10	550

Calhoun County.—The coal measures may extend a little way in the extreme northwest part of this county in Lee, Clarence and Sheridan townships, and coal is liable to be found as far as they go, as shown by wells reported only three or four miles from Albion, and given in connection with Jackson county. There are reports of coal through a number of different people here, near Boyd's farm, Sec. 13 and Sec. 24, T. 2 S., R. 4 W.

The report of four feet of coal six miles south of Marshall must be an error.

Jackson County.—This county has been quite fully described by Winchell and Rominger.

The New Hope mine on the west side of Sec. 27, T. 2 S., R. 1 W., has been already described in connection with the analyses of its coal, A5 and A6.

The Trumbull Mining Co., already referred to, on page 106, lies in continuation of the old Woodville mine to the northwest on Sec. 24, T. 2 S., R. 2 W. This coal is said to be 3 feet thick about 80 to 125 feet down.

This is a rather narrow trough and ran out toward the Michigan Central track. Mr. Robert Gage has operated on the same coal on the Laverty farm at Woodville.

The National Mining Co. did some exploring for coal on the farms of Mrs. J. Watts and E. W. Barber, southeast of Jackson Junction.

The coal lies mainly, it will be noticed, northwest of Jackson.

Coal 3½ feet thick was said to have been found on the Daniels farm, 2 miles west of the city, where, J mile from the city limits, is said to be 80 to 100 acres of coal about 3' 3" thick, at a depth of 105 feet. It is to be exploited by the Central City Coal Mining Co.

Some records near the Calhoun county line, which I owe to Mr. W. T. Chappell are of interest.

Well on farm of A. Burns, 3½ miles northeast of Albion,
near L. S. & M. S. R. R., O. A. Shadbolt, driller:

Dry sand	20	
Wet sand	50	
Clay	53	
Black shale	3	
Coal (Verne?).....	3	
Black shale	1' 4"	57' 4"
Fire-clay	4	61' 4"
Sandrock	3	64' 4"
Hard rock (FeCO ₃ ?).....	25	89' 4"
Sandy fire-clay	2	91' 4"
Sandrock	6	97' 4"
Coal (Saginaw?).....	88	185' 4"
Sandrock	0' 2"	195' 6"
Sandrock	5	200' 6"

On John Holmendinger's farm, ¾ mile away:

Sand	20	
Sandrock	27	47
Slate	6' 6"	53' 6"
Coal	0' 6"	54
Fire-clay	8	62
Gray slate	14	76
Hard rock (FeCO ₃ ?).....	1	77
Sandrock	73	150
On Barnes' place—		
Sand	64	64
Sandrock	90+	154+

Thus it seems as though we have in Jackson county, as around Mason and Lansing, a heavy sandstone splitting the shaly coal-bearing series, with coal below sometimes as well as above. The upper series is probably that which has been mined and corresponds to the Upper Verne. In the deep wells, reported in Vol. V, the lower coal seams, the Saginaw, etc., have apparently dropped out, and the sandstones merge together as they seem to do southeast of Corunna also.

We notice, too, that most of the coal seems to lie west and northwest of the city, although one of the Emerson shafts at least was southeast. The Porter mine (Fig. 5) and other abandoned mines were right in the city. The Eureka was northeast.

The coal formation seems not infrequently to lie in hollows eroded out of the limestone which lies underneath.

For instance, southeast of the city, Poole and Emerson had a shaft in the valley, while the hill adjacent was capped with Eocarboniferous limestone on sections 12 and 13, T. 3 S., R. 1 W.

Moreover the wells near Albion just cited are considerably outside the line of strike of the Eocarboniferous limestone from Jackson to Bellevue.

ERRATA,

Not Including Mistakes of Capitalization.

Page 28, line 1 from below, read W. F. Ward.

Pages 37, 175, 176. I have carelessly mixed up in my use the names of two prominent Saginaw men. Dr. H. C. Potter was president and superintendent of the East Saginaw Salt Mfg. Co., which put down the first well, but Dr. Geo. A. Lathrop was one of the promoters and kept the record.

Page 39, line 23 from above, for 57 read 5.

Page 43, line 5, for Discinesca here and elsewhere read Orbiculoidea, which has also been found at the air shaft of the Michigan mine at St. Charles and identified by Mr. Girty as O. missouriensis.

Page 54, line 16, before 650 read + instead of X.

Page 91, line 13 below, read analysis.

Page 105, line 3 from below, read July 23.

Page 166 is misnumbered 66.

Page 168, line 2 from below, strike out comma after Bangor.

Page 185, line 22 read O'Donnell and Spencer Co.

Page 186, line 13 for W.: read E.:

Page 202, line 25, for Milletts read Millett.