# MICHIGAN ACADEMY OF SCIENCE, ARTS AND LETTERS

## VOLUME I

CONTAINING PAPERS SUBMITTED AT THE ANNUAL MEETING IN 1921

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*Previous publications of The Michigan Academy of Science now known as The Michigan Academy of Science, Arts and Letters, were issued under the title, Annual Report of the Michigan Academy of Science. Twenty-two volumes were published, of which the first five are out of print. Copies of volumes numbered six to twenty-two are still available for distribution and will be sent on exchange so long as the editions last. Applications for copies should be addressed to the Librarian of the University of Michigan.*

*Annual Reports embracing the proceedings of the Academy will however, continue to be published.*

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## PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

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# NOTE

THE present volume of scientific papers is the first in a new series of publications of *The Michigan Academy of Science*. The twenty-two volumes which have been known as the Annual Reports of the Michigan Academy of Science, have been published under special appropriations of the State of Michigan. In 1921, however, the Academy and the University entered into an agreement for the annual publication of the Academy's papers. The new plan, involving a complete change in the form of the volumes as well as a change of title and involving also inclusion in the University's general program for scholarly publications, is inaugurated with the present volume.

The scholarly publications of the University are all under supervision of the Executive Board of the Graduate School in respect to the papers of the Academy the editor for the Board will work in collaboration with the editor for the Academy. Unfortunately, circumstances have combined greatly to delay the first volume, but hereafter prompt publication may be expected.

It will be noticed that the volumes for 1921 and 1922, the latter to appear in course of the present academic year, contain no papers in arts and letters in spite of the new and more comprehensive name of the Academy; but

sections in the humanistic subjects are now contemplated, their organization will soon be effected and subsequent volumes should show the new fields of interest and activity.

Finally, the University has welcomed the opportunity to establish closer relations with the Academy in its efforts for higher scholarship, original investigation and important contribution.

ALFRED H. LLOYD

OFFICE OF THE DEAN OF THE GRADUATE SCHOOL, UNIVERSITY OF MICHIGAN

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# CORRELATION AND THE PRICE OF COAL

A METHOD AND EXAMPLE OF MARKET-ANALYSIS

WILLARD L. THORP

## THE GENERAL PROBLEM

Markets are complexes of many heterogeneous forces. In them these forces, arising from quite dissimilar sources, converge. Some few markets have one force which predominates. Most of them are guided by such a complexity of influences that it seems well-nigh impossible to resolve the tangle into its component parts. It is the intent of this paper to present a method of market-analysis which shall determine and evaluate the fundamental and permanent forces at work.

Some few markets can be satisfactorily analyzed by mere inspection. But in most cases, the very complexity of the situation makes it impossible for the investigator to do more than merely conjecture. It is the purpose of this paper to present a method by which the investigator may scrutinize and evaluate forces, not on a basis of his own assumptions, but with a measure of scientific precision. The method employed is a mathematical one known as correlation. The first part of this paper is devoted to the theory of correlation, omitting the mathematical details involved; the second part deals with the specific application of this method to the bituminous coal industry.

## THE THEORY OF CORRELATION

If a careful comparison of two groups of phenomena demonstrates that the variations in one correspond to variations in the other, we say that correlation exists between them. For example, inasmuch as examination shows that an abnormal amount of iron ore is mined in years when there is also an abnormal production of steel rails, correlation exists between the production of iron ore and steel rails. Again, if by examining one thousand anthropometric charts it is found that the taller men are the heavier, then correlation exists between height and weight.

But it is not always easy to recognize such correlation. Imagine examining the records of five hundred cows in an effort to determine the relationship between the amount of feed per cow and the amount of butter-fat each produced. In such a case as this, where a great number of instances are employed, even graphic methods prove inadequate. But not only must we be able to recognize correlation, we must be able to evaluate it. For this purpose Karl Pearson, the eminent biologist, evolved the correlation coefficient.

This coefficient is an evaluation of the relationship between the variations of two groups of phenomena. It is an absolute number, i.e., it is not influenced by the size of the units, nor by the extent of the deviations of the data employed. It may range from + 1 to - 1. A correlation coefficient of + 1 indicates perfect direct correlation, with the two always fluctuating regularly in the same direction. A coefficient of zero indicates no correlation present. A coefficient of - 1 indicates perfect inverse correlation, with the fluctuations similar, but in opposite directions.

If, for example, we had the measurements for a number of students, and found that in every case an additional inch in height meant five additional pounds in weight, we could say that a correlation of + 1 existed. Although this is obviously not true, yet some direct correlation between height and weight does exist. Actual investigation might value this at + .6. To give an actual example, the correlation between the amount of coal produced and the number of days worked in the mines per year is + .926. In other words, fluctuations in the amount of coal produced and the number of working days are very similar.

Again, take a case worked out by H. L. Moore. The correlation between the annual change in the amount of

potatoes produced and the change in price is - .856. This means, then, that the fluctuations are simultaneous, but opposite; that a small price corresponds to a large production and vice versa. The correlation coefficient, then, is a measure of the relationship between the two groups.

But what does the existence of this relationship signify? It can have only three sources: first, it may be the result of the dependence of one variable upon the other," for example, the correlation between iron ore and steel rails, or the heights of fathers and sons; secondly, it may be caused by the dependence of both variables on some third factor, as the correlation between the hay and corn crops, due to the fact that both are dependent upon rainfall; thirdly, it may be purely fortuitous.

If we find that a relationship does exist, how can we tell whether it is organic, or merely the product of chance? The reliability of the correlation coefficient depends upon two things, the size of the coefficient itself and the number of observations made. Obviously, the larger the coefficient, the more certain one can be that an actual causal relationship exists. If, however, only a few examples have been considered, this high correlation co-efficient may be based on a purely fortuitous similarity of variations.

But if, as we expand our data, and find that, when we take more and more instances into consideration, the relationship remains as indicated, the probability of its being fortuitous rapidly grows smaller. For example, if a man throws "double-sixes" twice in succession, it signifies little. If he does it four times in succession, some might question; the throwing of "double-sixes" ten times in succession would cause most people to feel that it was not purely fortuitous, and lead them to examine the dice very carefully. As the number of instances increases, then, any relationship evident becomes more and more firmly established as causal and not fortuitous.

To sum up, the reliability of the results depends upon the size of the correlation coefficient and the number of instances employed. The correlation coefficients given in this paper are based upon twenty-eight items; in them, a coefficient of less than .300 may be disregarded, but one of more than .500 indicates in general a decided causal relationship.

## CORRELATION IN MARKET-ANALYSIS

And now, with this method of determining the strength of the connecting bond between variables, we are ready to attack the problem of market-analysis. Just what can our correlation coefficient do in the midst of the complexity of market forces? It may be used to determine the relationship of the fluctuations of one of these factors, such as supply, over a period of years, with those of other data to be explained, for example, price. The correlation coefficient can weigh these two sets of fluctuations and evaluate the relationship actually existing. It deals with them as they have acted in the dynamic situation, in the midst of all the other forces.

If the factor in question is of so little importance, or is so regularly offset by some other factor, that it has little influence on the variation of the data which we are analyzing, this lack of connection between the two is made apparent in a low correlation coefficient. On the other hand, if this factor is really influential, and is constantly exerting pressure on the other, there will naturally be similarity between their variations, and this will be demonstrated by a high correlation coefficient. Thus, correlation will evaluate the relationships as they have actually existed.

One must constantly keep in mind, however, the fact that the correlation coefficient does not explain. It merely states the fact that a relationship exists. It remains for one who has studied the market under consideration to interpret and explain the relationship disclosed.

## THE SPECIFIC PROBLEM

Having set forward a method for market-analysis, let us apply it to an actual case, the mine-operators' or producers' market, the first step in the marketing of bituminous coal. This is an especially interesting case because the market is so unorganized that the usual descriptive method proves absolutely inadequate. Another slight argument in favor of its use, is that reliable data are available, all of which come from government agencies.

## THE DATA EMPLOYED

The data employed cover each year from 1890 to 1918 and are as follows:

Supply.—The total quantity of usable fuel in net tons produced for each year, being the summation of coal shipped from the mine, coal made into coke at the mine, coal sold to local trade and employees, and coal used at the mine for steam and heat.

Price.—-The average realization value at the mine f.o.b. cars. This is based on reports made by the operators to the U. S. Geological Survey, stating amounts received for coal sold and estimated exchange value for coal not sold. The change in general price level has been eliminated by expressing these prices in terms of the 1913 dollar by means of the index numbers of the U. S. Bureau of Labor Statistics.

Demand.—A composite expression based upon the conditions which determine the use of coal each year.

Since twenty-eight per cent of the coal is consumed by railroads, fifty per cent by industrial establishments, and sixteen per cent by domestic users, variations in the demand for coal result from fluctuations in railroad transportation, the general business situation, or in domestic demand. The fluctuations in railroad transportation may be represented by variations in total freight-ton miles per year; the fluctuations in business conditions by the amount of pig-iron produced; and the domestic demand by the temperature of the winter

months, which also conditions the other uses to some extent. By properly weighting these three items, and combining them, a composite is obtained which is the expression of the demand in terms of the conditions which determine it.

Through the use of data expressing annual fluctuations only, the variations of the market due to purely temporary forces have been largely eliminated. It is necessary, however, to remove the secular trend also. In the matter of production, for instance, we find a steady increase from year to year, due to the growth in population and the expansion of industry. It has seemed best to eliminate this by expressing each variation in terms of the percentage change from the previous year.

To make sure that such a method involves no substantial error, I have worked out all results on a basis of first variate differences, and also variations from a nine-year moving average, and obtained approximately the same results. Both these latter methods involve, however, errors which make the method of percentage differences appear to be the most accurate. If we do express each year of coal production as a percentage of the previous year, we find that there is an average increase of six and four-tenths per cent. Were there no other influences present, the production would increase regularly at this rate. But in some years it increased more, in others, less. For our purpose, any increase more than six and four-tenths per cent will be considered an increase in production, and any less than that a decrease in production. Our problem is the analysis of these fluctuations about what we might call the "normal trend" of the data.

The application to the data of the method just stated gives the following results.

## RELATION OF DEMAND AND SUPPLY

The correlation between demand and supply is expressed by a coefficient of + .742. Obviously, this denotes a marked similarity between their fluctuations. In other words, production of bituminous coal conforms very accurately to the demands of the market. But which way does the causation run, from demand to supply, or from supply to demand? This can be answered by recalling the composition of our demand expression. For a large amount of coal produced will have, at most, only a slight influence on the amount of freight-ton miles, since coal is only one of the many factors determining the amount of freight carried. An increase in the amount of freight carried will, however, have a great effect on the amount of coal produced. Likewise, an increase in the amount of pig-iron produced will not be the result of an increase in the amount of coal produced, but rather a cause for the production of more coal.

As for temperature, it would take an enormous increase in the production of coal to affect it in any way, whereas a small increase in the temperature will have a decided effect on the amount of coal produced. In other words, since the demand is determined by many outside factors quite independent of the supply of coal, the line of causation runs almost entirely from demand to supply. That is, the demand is determined externally, and the supply conforms to it.

If pig-iron and freight alone be considered as determining demand, the correlation between demand and supply becomes + .863, in which case the fluctuations were similar in twenty-four of the twenty-eight years under observation.

Other interesting facts can be noted as the correlation coefficient is developed, e.g., that since 1906 there has been much greater conformity between supply and demand than before that date. This would indicate that the market became better organized at that time, or possibly that new methods of marketing were introduced.

## RELATION OF DEMAND AND PRICE

Upon introducing price into our discussion, we find that the correlation coefficient between supply and price is - .090, and that between demand and price is - .243. That the latter is so high is due to the peculiarities of the temperature variations, for if temperature be not considered, the correlation between demand and price becomes - .087. These are negligible. Apparently, then, neither changes in supply nor changes in demand have any effect on price. Does this mean that supply follows demand so closely that the price is not affected by variations?

We know, however, that price does vary. Why? The reason is soon seen in the market itself. Coal is sold either by contract or in open market. Since eighty per cent of the coal is used by railroads, public utilities, and large industrial establishments, and since they can foresee with considerable accuracy their demand, a system has grown up whereby these large buyers purchase almost all their coal on annual contracts, and enter the spot market only under abnormal conditions. Likewise, the jobbers get their coal on contract, so that much of the spot market coal is contract coal as far as the producer is concerned.

These contracts are generally for the coal year, April 1 to March 31. Consequently, the producer's market for coal is chiefly a contract market. A fluctuation in demand cannot influence the price until the contract then in force expires. Therefore, we should expect the fluctuations in price, instead of correlating directly with fluctuations in demand, to lag considerably behind. This hypothesis is tested by correlating the demand of 1890 with the price of 1891, the demand of 1891 with the price of 1892, etc., as a result of which is a correlation coefficient of + .684. This is not saying that a big demand would not affect the price you have to pay for coal (it certainly would), but that, as far as the actual producer is concerned, his output is already contracted for, and he will not benefit from these higher prices until the new coal year, when new contracts are entered into. It is interesting to note that this rule has held without a single failure since 1906.

## RELATION OF SUPPLY AND PRICE

As already noted, the correlation between supply and price of the same year is - .090. By lagging the price one year, however, as we did when correlating demand and price, we find that a correlation of + .569 exists. This is especially interesting when compared with the same correlation in the cotton market which is - .812. Why is it that the coal market should reverse the situation and a large supply be followed by a high price?

There are two possible explanations for this large plus coefficient. First, coal may be an industry entailing increasing cost, and the mining of this great supply, involving a big expenditure, may have caused this high price. Let us use our method in testing this hypothesis. New data must be introduced which may be called labor cost. This represents the amount of labor required to mine one ton of coal. The estimate is made by dividing the product of the number of days worked and average number of employees, by the number of tons produced. Since labor is from sixty to eighty per cent of the total mining cost, a variation in amount of labor required would be the greatest factor in variations in the cost of mining. But the correlation existing between labor cost and amount produced is only + .208. This by no means justifies the hypothesis that increased production is accomplished only at increased cost.

A further examination of the data brings out some illuminating facts. If the supply of one year and the labor cost of the following year be considered, there is a correlation of + .556. There is, therefore, a real relationship between supply and cost, but with a time element introduced. Apparently, the producer knows that he is to have this larger cost, for the price which is set early in the year and which must consider the estimated cost of production, shows a relation to this cost of the same year of + .378. Now comes the question, Why does this increased cost come the year after the large production rather than the same year?

There seem to be two factors in this relationship. First, there is a natural delay. This labor cost is affected by the number of men employed. As production increases, the number of men will remain the same for a while, and then increase. Similarly, as the amount produced decreases, the same number of men will be employed until there has been a considerable decrease. Consequently, the labor cost would naturally fall behind production. Secondly, much of the mining cost is in the opening up of new seams, etc. In the year of great production, all easily available coal is mined, so that, during the following year, a considerable amount of labor must be employed in opening up new seams, thereby resulting in a higher labor cost. In other words, the increased cost is not that of producing the large amount of coal, but of regaining the ground lost by this large production. At any rate, it is true that a large supply results in a high cost for the next year, and this enters, to some extent, into the determination of price.

This is not sufficient, however, to explain the large coefficient which we found between supply and price. The second reason, and the most important one, is as follows. In the discussion of the theory of correlation, the statement was made that correlation might be the result of a direct line of causation, or of influence upon both variables by the same force. This latter alternative is the real explanation of this large plus coefficient; for demand is an independent variable, coming into the market from outside. Its fluctuations determine the supply for that year and also the price for the next year. Is it not, consequently, to be expected that there will be a great similarity between the supply one year and the price the next, though there be no direct connection between them? There is no direct line of causation between supply and price. There is a similarity of variations because both are determined by demand. There is a small indirect line of causation from supply to price through cost of production.

## SUMMARY OF THE SPECIFIC PROBLEM

Demand is the predominating force in the bituminous coal market. Supply conforms very closely to demand. This demand is the result of business conditions, railroad transportation, and temperature. Demand does not influence price until the following year. This is due to the system of contracting now prevalent. Supply enters into price-fixing only as it influences the cost of mining in the following year.

These are the forces which have been active throughout the last twenty-eight years. In this paper, I have considered only these most important factors. It would be possible to extend the investigation to include relations of profits, wages, cost of materials, strikes, car shortages, introduction of machinery, etc., to market conditions. Such extension must be made in order to obtain a complete analysis.

## SUMMARY OF THE GENERAL PROBLEM

As we approach nearer to standardization and regulation of markets, it is essential that we have a satisfactory means of market-analysis. Our general theory of markets has been fully developed. It now remains for the economist to consider these general principles and qualify them in the light of each separate market. By the use of a quantitative study, the means for which I have suggested, he can now make a complete market-analysis. If this method succeeds in such an unorganized market as that for bituminous coal, it ought to be of even greater value in those which are more standardized and highly organized.

COLUMBIA UNIVERSITY

# AN ABSTRACT OF "A HISTORY OF THE MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY BY R. C. ALLEN AND H. M. MARTIN"[1]

HELEN M. MARTIN

The Geological Survey of Michigan is almost as old as the State itself, having been founded by Act 20 of the Legislature of 1837. Dr. Douglass Houghton was appointed state geologist, but the First Survey terminated in 1845 with the untimely death of Dr. Houghton. In 1859, by Act 206 of the Public Acts of 1859, the Legislature provided for the resumption of the Geological Survey, but the outbreak of the Civil War interrupted the work of 1861; it was not until 1869 that the Third Survey was organized under Act 65, 1869, the law under which the Survey now operates.

In the accounts of the Jesuits, there are disconnected observations on rocks and minerals and soils of the region of the Great Lakes, as well as notes and descriptions of routes of travel, mainly along waterways and the coast of the Northern Peninsula. These descriptions were chiefly geographic in character, as were those of other early explorers, Alexander MacKenzie in 1789, General Cass in 1819, Major Long in 1823, and H. E. Schoolcraft in 1831.

To Douglass Houghton and his assistants of the First Survey, we owe the earliest organized statements concerning the geology of Michigan. In 1837 Michigan had fewer than 24,000 white inhabitants, located mainly about Detroit and Saginaw. To many of these people, as well as to the people of the East, Michigan was a land of muskeg swamps and sand-hills. It was largely to eradicate these ideas that Douglass Houghton planned the first survey.

[1]The contribution by the first author covers the years 1837-1872, by the second, 1872-1920.

Although organizations of the first surveys of Massachusetts, Tennessee, Maryland, New Jersey, Connecticut, Virginia, Maine, New York, Ohio, and Pennsylvania preceded that of Michigan by one to seven years, their results were as yet so meagerly available that they were of little aid to Dr. Houghton in planning those labors that were to open up the wilds of Michigan. It is interesting to note here the evidence of Houghton's vision and genius, that the Survey as organized by him (Act 49, 1838) is in the main essentials the plan existing today in Michigan and a number of other states. Its plan provided for geological, topographical, zoological, and botanical departments, each in charge of a specialist under the direction of the state geologist.

Since the idea of Federal and State cooperation is supposed to have originated in connection with making a topographic survey of Massachusetts, and to have been the idea of Mr. Henry F. Walling, it is interesting to note in passing that in 1844 a contract to make such a survey was entered into by Douglass Houghton and the Federal Land Office.

Straitened finances and the hostility of the Legislature caused the abolishment in 1840 of the Departments of Botany and Zoology, over the strong but futile protests of Dr. Houghton. The Legislature could see no early benefits from such labors.

The law of 1837 contemplated the completion of the Survey in four years, but it was soon apparent that a long time would be necessary to make even a cursory examination of the entire State. The incompleteness of the United States linear surveys hindered the work. Nevertheless, a large part of the field-work was accomplished in 1842, when the act creating the Survey expired, leaving a large part of the Upper Peninsula unexplored. Dr. Houghton, therefore, set about effecting a plan of connecting the linear surveys with the minute geological and mineralogical surveys of the country. In 1844 he laid his plan before the Government. Its feasibility was comprehended and Houghton given the contract of running 4,000 miles of lines at a price but little, if any, exceeding that which would have been paid for a linear survey alone.

The plan was abandoned after his death, but had the system remained in operation, we should have had at that early date information which was acquired decades later, and with vastly greater expense and labors. The published results of Houghton's survey appear in seven reports to the Legislature and in a number of short communications relative to the development of salt-springs and other subjects. (This we expect to be re-published, together with a more complete history of the survey, in a forthcoming volume issued by the Historical Commission.)

The final report was nearing completion when it was interrupted by the death of Dr. Houghton October 13, 1845. The state topographer immediately impressed upon the Legislature the importance of entrusting the completion and the editing of the final report to Dr. Houghton's assistants, but though the Legislature responded by authorizing the governor to appoint a suitable person, no appropriation was made for his expenses and remuneration. There is no record of such an appointment, and certainly the work was not done. The vast collection of notes, maps, and manuscript, representing eight years of unremitting toil, was lost. Dr. Winchell reports that the administrators of Dr. Houghton's estate employed William A. Burt and Bela Hubbard to compile from the field-notes of 1845 results of the great work of that year. These reports were not published, but were undoubtedly incorporated into the Jackson report of 1849-1850 without proper acknowledgment to Dr. Houghton.

Just how much was accomplished by Houghton is not known, but it is evident from fragmental reports in House and Senate documents that he had attained a fairly clear understanding of the succession and structure of the Palaeozoic rocks, had blocked out the Michigan Coal

Basin, understood in a measure the later history of the Great Lakes, and had traced the position of their shore lines, had called attention to the importance of the deposits of natural brines, gypsum, coal, peat, marl, clay, limestone, iron ore, and copper, and had discovered gold. The influence of his report on the copper-bearing rocks was a factor in attracting capital to the Copper Country and in exercising a wise guidance on early prospecting and financial operations, and also in hastening the construction of the first canal and locks around the falls of St. Mary's River. The entire cost of the Houghton Survey was $32,829.03.

A little more than a year after the suspension of the survey under Dr. Houghton, Congress passed an act embracing provisions for the geological exploration of the Lake Superior Land District organized by the same act. Under this act, Dr. C. T. Jackson was appointed to execute the required survey. During two field-seasons, he prosecuted the work, then presented his report of 801 pages and resigned. The work was continued and completed by T. W. Foster and J. D. Whitney. These reports appear as U. S. Senate Documents. Some of the assistants of Dr. Houghton were employed by Jackson, Foster and Whitney, and Houghton's notes and results were made use of in other ways to such an extent that much of the credit rightfully belongs to him, though no proper acknowledgment of it is made by these geologists.

The Second Survey was inaugurated in 1859, Act 206, and suspended in 1863 by the failure of the Legislature to make an appropriation for its continuance. The act authorizing the Survey was almost identical with that of 1837, empowering the governor to appoint a suitable person to finish the geological survey of the State and to furnish "a full scientific description of the rocks, soils, and minerals and of its botanical and other natural productions."

Dr. Alexander Winchell, the professor of geology in the University, was appointed state geologist by Governor Wisner, March 9, 1859. In December, 1860, Dr. Winchell made a report to the governor under the title *First Biennial Report of the Progress of the Geological Survey of Michigan*. This is the only publication of the Second Survey and is without map, sketches or other illustrative material, omissions which impair its usefulness. Evidently, the Legislature disapproved the emphasis placed on the botanical and zoological investigations, for by Act 64 of 1861, the state geologist is directed to restrict his labors to the geological department exclusively.

The report records the activities of Dr. Winchell and his assistants, as well as the results of their labors. In this document, Dr. Winchell gives the only orderly and connected general account of the State which had been made. He dismissed the non-fossiliferous rocks west of the meridian of Marquette with a brief statement of the works of other geologists. But the fossiliferous rocks were studied carefully by him. The report describes them in considerable detail and compares them with similar formations elsewhere. Dr. Winchell made a large collection of fossils, studied the non-metallic industry of the Southern Peninsula, and made a catalog of its plants, mammals, birds, reptiles, and molluscs.

The First Survey was devoted mainly to the Northern Peninsula, the Second to the Southern. When it is considered that the work extended but a little over two years, that the appropriations were small, and that the time Dr. Winchell was able to devote to the Survey was limited by his university duties, it is not surprising that the published results were not numerous.

The Second Survey was definitely terminated by the Legislature by joint resolution of the House and Senate which directed the "late state geologist to transfer to the Board of State Auditors all property of the survey, etc." The total appropriation for the Second Survey was $9,000, of which only $6,000 was drawn from the treasury.

By the year 1869, a strong public demand had arisen for a resumption of the geological survey, and Governor Baldwin in his annual message strongly advocated "a thorough comprehensive examination of the whole State." In due time a bill authorizing its resumption was introduced by Mr. Yawkey; it was referred to a joint committee of the House and Senate. The report of this committee reviewed the previous geological work in Michigan and legislation concerning it, and concluded with a very urgent recommendation that a most comprehensive and detailed survey be made — if not in both peninsulas, at least in the Northern. The bill embodying these recommendations, *Act No. 65, Public Acts 1869*, was promptly passed March 26, 1869.

The act created a Board of Geological Survey, an ex officio body consisting of the governor, the superintendent of public instruction, and the president of the State Board of Education. The Board was authorized "to appoint a suitable person possessed of the requisite knowledge of the science of geology who shall be Director of the Survey," and, at the nomination of the director, such assistants as were necessary to fix salaries and in general "to regulate all expenses incident to the survey."

The director was charged with all responsibility for the scientific and administrative work of "a thorough geological and mineralogical survey of the State, embracing a determination of the succession, arrangement, thickness, and position of all strata and rocks; the mineral character and contents and their economical uses; an investigation and determination of the organic remains of the State; a general examination of the topography, hydrography, and physical geography of the State; an investigation of the soils and subsoils, and the determination of their character and agricultural adaptation; the investigation of all deposits of brine, coal, marl, clay, gypsum, lime, petroleum, metals and metallic ores, building stones, marble, grit stones, materials for mortar and cement, mineral paint, and all other

productions of the geological world capable of being converted into the uses of man."

The act provided for a continuing annual appropriation of $8,000, and directed that one-half of the expenditure be devoted to work in the Northern Peninsula, including the "collection of statistics and history of the mineral, manufacturing, and transportation interests; to the preparation and compilation of accurate maps showing the topography, geology, and timber, and also portions of mines, roads, and improvements; to the determination of the position and structure of the minerals and mineral rocks; to compiling and collecting of all useful knowledge that would be of practical value in finding and extracting ores and mining and smelting in the districts of the Upper Peninsula known as the iron and copper regions."

A joint resolution of the House and Senate was passed asking Congress to appropriate annually for three years $8,000 to assist in making the survey, but the request proved futile. It is noteworthy that there was no provision made for botanical and zoological investigations.

On April 24, 1869, a month after the act became effective, Dr. Alexander Winchell was for the second time appointed director of the Survey. But Dr. Winchell's second administration was destined, like the first, to be short-lived. The causes which led to his resignation are not known. His brother states they were of a political nature. At any rate, the Board seriously disagreed with Dr. Winchell in regard to the scope and management of the Survey. Dr. Winchell could not be reconciled to the decisions of the Board and tendered his resignation March 21, 1871. Dr. Winchell presented a very comprehensive plan for the completion and publication of the results of the survey, which the Board would not accept. The history of the work during the next twenty years is a demonstration of the unwisdom of the failure to carry out Dr. Winchell's plans.

During the two years 1869-1871, Dr. Winchell and the Board interpreted the clear intention of the law "that the moiety assigned to the Upper Peninsula should be expended in the development of the iron and copper interests of that part of the State," and decided that, in view of the limited means, it was wise "to devote the entire annual moiety to the iron interests in 1869, and to the copper interests in 1871." Accordingly, a contract was signed with Major T. B. Brooks by which he was required to complete a survey of the Marquette Iron District; for this he was to receive $4,000. A similar contract was signed the following year with Prof. E. J. Pumpelly, by which he was required to conclude such portion of the survey of the copper region as could be accomplished with the desired degree of unity and completeness for the other $4,000." The work of Major Brooks began June 4, 1869, and continued through 1871. The work of Professor Pumpelly began June 1, 1870.

In the Northern Peninsula, the areas actually subjected to examination were the Copper District of Portage Lake; the Marquette and Gwinn Iron Districts; St. Mary's Peninsula; the Green Bay region; and in the Southern Peninsula the Cheboygan, Little Traverse Bay, Thunder Bay, Au Sable River regions, the valleys of the Manistee and Pere Marquette rivers, Kent and Lapeer counties, and many other smaller districts. Investigations were made of the fish, lumber, and forests of the east and west shores, and of the fruits of the west-shore district, as well as of some meteorological problems.

Dr. Winchell planned and, in great degree, assembled the material for a series of publications on the physiographical features of the State, its general geology, economic geology, resources, palaeontology, zoology, botany and antiquities, which would have been of the utmost value in the development of the State.

Dr. Winchell asked an appropriation of $60,000 with which to complete the work he had mapped out, but his plan and hope failed. He could not accept the plan of the Board to "give the survey a more practical direction and to secure more direct and immediate benefit." The Board had not the vision nor the scientific insight to accept Dr. Winchell's plan and accepted his resignation April 17, 1871, and the same day appointed Dr. Carl Rominger to continue the survey of that part of the State not included in the investigations of Major Brooks and Prof. Pumpelly.

In the meantime, the Board had proceeded to have the law changed (*Act 179, Public Acts 1871*) in such a way as to abolish, not only the powers and duties of the director, but also the office itself, and to center the full responsibility as well as authority in the Board. The Legislature amended the law in accordance with the desires of the Board, at the same time repealing the provisions requiring an equal division of the work and expenditure between the Northern and Southern peninsulas. In other respects the law remained unaltered.

In 1871-1872, Dr. Rominger completed a survey of the Palaeozoic rocks which cover the western end of the Northern Peninsula from Marquette to St. Mary's River, and the studies of Brooks and Pumpelly were brought to a close. In 1874, the results of these studies were published as Volume I of the Survey reports, viz.: *Iron-Bearing Rocks*, by Major T. B. Brooks; *Copper District*, by Raphael Pumpelly and assistants; *Palaeozoic Rocks*, by Carl Rominger (Volume I is accompanied by a geological atlas, sections and statistical data); and Volume II, containing a lithological description of specimens of rocks, by Alexis A. Julien, Major Brooks, and Chas. E. Wright. The appearance of these reports marks an epoch in the study of the geology of the Northern Peninsula. Twenty-one years had passed since the reports of the Jackson-Foster-Whitney surveys had been given to the public.

In the interim, a few articles on the general geology appeared in certain periodicals, but no considerable advance in understanding of the general geology of the Northern Peninsula had been made. The studies of

Pumpelly and Brooks were based on those minute observations which have characterized nearly all subsequent works in the region. Pumpelly's *Paragenesis of the Minerals Associated with Copper* is one of the classics of geology, and Marvin's *Detailed Structure and Stratigraphic Sections* remains even today a standard for comparison and correlation of the formation members of the vast thickness of sedimentary beds and lava flows of the copper-bearing series of Keweenaw Point. Brooks's report was devoted mainly to the economic aspects of iron mining and smelting; nevertheless, a great advance was made in his studies of the structure and. succession of the Huronian system of the Marquette Range.

Brooks was the first to perceive that the Marquette Range is a great synclinal trough forty miles in length, pitching westward from the vicinity of Marquette. In company with Pumpelly, he also made reconnaissance examinations of the Gogebic range from Penokee Gap in Wisconsin eastward to Lake Gogebic in Michigan, and determined correctly the relations of the Laurentian, Huronian and Keweenawan systems in this range. Numerous details of the geology of the Menominee and Felch Mountain ranges were also given. Rominger's report on the Palaeozoic rocks is the first comprehensive description of the geology of St. Mary's Peninsula, and maintains the high standard set by Pumpelly and Brooks.

During the four years 1872-1876, Dr. Rominger was engaged practically alone in the work of the Survey. The results of his researches are embodied in Volume III of the Survey Reports, which are a discussion of the geological structure of the Southern Peninsula, confirming and carrying farther the views and researches of earlier geologists, Houghton and Winchell, on the "basin structure" of the Michigan area. The book contains also the record of the state salt-inspector, Dr. S. S. Garrigues, and also by far the most important record of Dr. Rominger's studies, a carefully elaborated monograph on the indigenous fossil corals of the State, the first treatise of a state survey devoted wholly to corals.

In the spring of 1877, the Board of Geological Survey, although comprehending the valuable and arduous work of earlier geologists, realized that investigations were only commenced, and that it should be the duty as well as pride of the citizens of the State to have the territory fully examined. Therefore, the Board accepted Dr. Rominger's plan to make careful detailed examinations of certain small circumscribed areas so related as to embrace the most important rock formations developed in the region. This work, like all work before and practically all since, was hindered and delayed by lack of topographic maps, and the necessity of depending on the government maps of the linear surveys of the United States, upon which the topography was omitted or inaccurately recorded. The need, however, for topographical work, as well as for general reconnaissance, resulted in the discovery of many "instructive" outcrops, which would otherwise have been overlooked.

Three summer seasons were spent in the investigation and construction of a special geologic and topographic map of the district about Marquette, Negaunee and Ishpeming. Dr. Rominger also examined the then important mining localities, Washington, Champion, Republic, Spurr, and Michigamme. The season of 1880 was spent in a similar careful examination of the Menominee region. (The reports are published as Volume IV.) During 1884, the state geologist continued work in the copper and iron country, but although the report of the work would have been of value to the mining companies, it was so small that the Board deemed it inadvisable to print it, and it did not reach the public until ten years later.

Dr. Rominger continued as state geologist until May, 1885; when he was succeeded by Mr. Charles E. Wright of Marquette, who had been commissioner of Mineral Statistics since 1878 and a member of the Board of Control of the Mining School at Houghton.

Mr. Wright remained state geologist until his death in 1888. During the field-season, he was engaged in making topographic maps and sketches to illustrate the geology of the Northern Peninsula, and in the collection of 3,300 specimens of rocks to be the nucleus of the collections of the University and various colleges. In the Southern Peninsula he visited the salt wells and prepared sixty sections of deep borings. But at the time of his death, in spite of zealous labors to fit himself for the position of state geologist by years of research and study, and in spite of his plans and work laid out on a large scale, nothing was available for publication and many facts and conclusions reached by him were lost to the public.

Upon the death of Mr. Wright, the Board responded to certain pressure brought to bear upon it and appointed Dr. M. E. Wadsworth, director of the Mining School, as state geologist. An arrangement was made with the school whereby Dr. Wadsworth was permitted to manage that institution, and at the same time act as state geologist. That such a union of offices was unwise was brought to the attention of the Board, but the inadequacy of the Survey funds available was deemed sufficient reason for carrying out the plan.

With Dr. Wadsworth, the Survey at last secured offices of its own. Up to that time, the Survey had had no other habitation than the private offices or homes of the various geologists. In May, 1889, the Mining School gave a room, rent free, about 25 by 30 feet in size, in which the indoor work could be prepared and in which was stored all property of the Survey except manuscripts and published volumes. The school also allowed the Survey unrestricted access to and use of all departments and laboratories, thus providing a means of more rapid indoor work, analysis and preparation of specimens and thin sections, map work, etc., which should have hastened publication of reports.

Dr. Wadsworth continued Wright's plan of detailed surveys of the iron districts, exploring in 1888 between Iron River and Gogebic Lake, and between the state boundary and Township 46 on the north, and in mapping unsurveyed districts near the Marquette district; and in 1889 extending the exploration westward from Lake Gogebic to the state boundary, and in exploring the eastern boundary of the copper-bearing rocks.

In 1889, arrangements were made with the U. S. Geological Survey, whereby the State Survey devoted its time mainly to the economic geology of the State, leaving the purely scientific studies, particularly palaeontology, to the U. S. Survey. Upon the recommendation of Dr. Wadsworth, the Board voted to correspond with Prof. Mendenhall, superintendent of the Coast and Geodetic Survey, asking him to undertake a triangulation of the State, but, apparently, nothing further was done to aid the inauguration and progress of the much-needed topographic survey.

The Board of Geological Survey of 1890-1892 seems to have taken a lively personal interest in the work of the Survey. They accepted Dr. Wadsworth's very ambitious plans, but from the minutes of the meetings it is very evident that they were "dissatisfied and disappointed" with the slow output of material for publication, and the fact that thin sections and specimens were not being prepared and sent to the various schools and colleges with greater rapidity. The Board visited the offices of the Survey at Houghton. At a joint meeting with the Board of Control of the College of Mines, it was decided that Dr. Wadsworth should be released from his duties as director of the college from August, 1891, to May, 1892, "to such an extent as was necessary to enable him to complete the work to date."

The Board also requested Dr. Wadsworth to furnish an annual report not later than Jan. 1, 1891. In this request the Board was disappointed, and the somewhat acrimonious correspondence which followed led Dr. Wadsworth to tender his resignation March 3, 1891. This was not, however, accepted, and, furthermore, a sharp communication was sent informing him that unless material required for the annual report was forwarded by April, the Board "would move its property to Lansing, discharge its present employees, and employ such others as it saw fit."

A committee was appointed to visit the state geologist and to ascertain progress on the report. The results of this investigation and recognition of Dr. Wadsworth's plea "that suspension of the operations of the Survey would result in putting back the publication for many years, or, more likely, cause the loss to the State of the past ten years' work," caused the Board to retain Dr. Wadsworth as state geologist, and to write to him that their differences had arisen from a misunderstanding of the amount of work to be completed, and that "the Board further reports that Dr. Wadsworth has the Survey thoroughly organized, and, *so far as the time given the Survey permitted*, is making considerable progress."

Although most of the papers comprising Volume V were in the hands of the Board in June, 1892, despite the fact that it was the lack of published reports which had urged the Board to its singular activity, the Board retired with the volume unpublished, printing only the *Report of the State Board of Geological Survey for 1891 and 1892*. To this are appended exhibits setting forth the expense of the Survey, the reports of Dr. Rominger, Mr. Wright and Dr. Wadsworth. This is the first and only report made by a Michigan Board of Geological Survey, and the only contribution of the Wright-Wadsworth administration. As it is without maps or illustrations, it is of much less value than it otherwise would be.

In the report, the Board includes recommendations for certain remedial legislation which were significant of future changes in the conduct of the Survey: first, that a room in the Capitol be set aside for the Geological Survey; second, that the appropriation be increased so that the entire time of competent geologists could be secured, thus paving the way for offices in Lansing with a director of the Survey both independent of Mining School and University, for the placing of the finances of the Survey on a plain business basis when the work of the Survey should no longer be hindered by the divided interests of the. director, but the compensation of the director be such that he could devote his entire time to the Survey. A recommendation to abolish the office of commissioner of Mineral Statistics and transfer his duties to the Survey, brought results twenty years later. The Legislature took no action at that time, but eventually the recommendations were carried out and the successors to Dr. Wadsworth devoted their undivided efforts to the Survey.

The succeeding Board acted upon the recommendations of their predecessors to the extent of considering legislation to incorporate the office of Mineral Statistics with the Survey and to appoint a state geologist independent of the College of Mines. Informed of this, Dr. Wadsworth offered to resign as president of the Mining School and devote his entire time to the Survey, if his compensation would be placed at $4,000 a year. The Board did not accept Dr. Wadsworth's proposal, and in July, 1893, appointed Dr. Lucius L. Hubbard of the Board of Directors of the Mining School to the office of state geologist, and Dr. A. C. Lane as assistant state geologist.

With the appointment of Dr. Hubbard, the Survey entered upon a period of thorough reorganization. It was severed from the Mining School and the University; the efforts of the directors were not henceforth to be divided with other interests; and the Survey was no longer to be an appendage to the University or to the College of Mines, a condition considered by the Board to be beneficial to those institutions, but detrimental to the Survey.

On October 6, 1893, the Board of Control of the Mining School passed a resolution giving the Survey permission to erect a suitable building on the east side of the

Michigan Mining School property, and to occupy it rent free as tenants at will of the Board of Control of the Mining School. The offer was accepted, and through the efforts of Dr. Hubbard the citizens of Houghton contributed $1,100, to which the Survey added $1,500. A small building, a story and a half high, equipped with a fire-proof vault, was erected and at last, after an existence of over half a century, the first department of the State to be created received housing of its own.

Up to this time, the history of the achievements of the Third Survey is mainly a record of exploration and progress in the Northern Peninsula, aside from the brief interrupted work of Prof. Winchell, and the lonely work of Dr. Rominger, and some records and statistics collected by Mr. Wright on the salt and gas wells of the Southern Peninsula. But since the United States Geological Survey was at this time completing the *Monograph on the Lake Superior District,* and since further work by the Michigan Survey would lead to duplication, Dr. Hubbard agreed to continue state survey work only on Keweenaw Point and Isle Royale.

Exploration was extended to the Southern Peninsula under direction of Dr. Lane. He had been engaged in making microscopical studies of the thin section of Michigan rocks collected by Mr. Wright, and had carefully worked over the notes and records of gas and salt wells left by Mr. Wright. From these, he prepared the first important contribution since that of Prof. Rominger to the literature of the geology of the Southern Peninsula, *The Geology of the Lower Peninsula with Reference to Deep Borings.*

During the year 1895-1896, Dr. Hubbard was engaged in intensive field study of the copper-bearing rocks, Keweenawan Series on Keweenaw Point, and at the same time Dr. Lane was engaged in making a similar study of the same series of rocks, which compose the unique Isle Royale. Dr. Hubbard made particular studies of the acid intrusives of the lower part of the series and obtained many data, which enabled him to elucidate many valuable details of structure and to interpret results of exploration, particularly near Portage Lake. Dr. Lane's studies of Isle Royale were similar to those of Dr. Hubbard, but included minute studies of the copper-bearing rocks of the island, their origin, composition, structural and topographic relations, and the geological processes by which they were metamorphosed to their present condition. Dr. Lane reported also on prehistoric copper mining on Isle Royale.

The reports of the two surveys embody the highest type of geological work; they were accompanied by valuable maps and were ready for publication in December, 1896. But they also were fated to delay in printing. For some reason, the Board of Auditors refused publication of Survey reports unless authorized by the Legislature. This caused a delay of two years and resulted in the passing of Act 79 of the Laws of 1899, which authorized the publication of Survey reports. After the passage of this act, the reports were published by Dr. Hubbard's successor, though properly belonging to Dr. Hubbard's administration.

Many inquiries about the economic mineral deposits came to the Survey office from people within and without the State. Since lack of data on the exact location of such deposits was a serious drawback to exploration and development, the Survey planned to accumulate it. Dr. Hubbard laid out a plan which was to determine the geological structure of the Southern Peninsula. His plan was to make accurate examination (by county unit) of several segments of the Michigan Basin, as the geology of any given segment would approximate that of any other; to begin simultaneously on different parts of the formation; to construct maps showing surface and rock contours, and to receive information in regard to the economic aspect.

In the consummation of this plan, field-work was carried on in Huron, Sanilac, and Monroe counties by Dr. Lane, Dr. C. H. Gordon, and Prof. W. H. Sherzer, respectively. The work was begun most auspiciously; the field-work was completed late in 1897 and the manuscript submitted early in 1898, but, because of the refusal by the Board of State Auditors to order printing of plates for the county bulletins, the publications did not reach the people of the State, for whom they were intended. Pending legislation, Dr. Lane addressed a number of farmers' institutes on the subject, *The Best Farm Water Supply*. "This," says Dr. Hubbard, "seemed the best medium available to bring before the people a part, at least, of the results of the Survey work."

By 1895, the exhaustion of the "inexhaustible supply of pine" threatened the continuance of the salt industry in the Saginaw Valley, unless a cheap fuel could be supplied. This caused a rapid development in the coal areas, and led in 1898 to Dr. Lane's report on the Coal Basin to help development and give the landowners intelligent information about the economical development of their land for coal-mining purposes. To make the report available, it was printed serially in the Michigan Miner, although it appeared later in Volume VIII. It may be said here that all these reports were eventually printed, but, since the delay in printing rendered the work of the Survey temporarily useless, Dr. Hubbard declined to continue county surveys on the same scale as those already surveyed. As a result, in the season of 1898 the county survey was carried on only in Tuscola County, where Prof. C. A. Davis worked almost alone.

On June 10, 1899, Dr. Hubbard tendered his resignation. His administration had been most efficient; he had thoroughly reorganized the Survey, perfected for its development a plan which still remains in effect to some extent, surrounded himself with competent assistants, and, although sadly embarrassed by the unaccountable opposition of the Board of Auditors, had secured results of benefit to the State.

In April, 1899, the Board of Geological Survey elected Dr. A. C. Lane state geologist. Dr. Lane had been connected with the Survey during Dr. Wadsworth's administration and was assistant state geologist with Dr. Hubbard. He was thoroughly conversant with the plans of Dr. Hubbard for the development of the Survey and continued to put them into execution.

The main office of the Survey was now transferred to Lansing and Mr. Savicki left in charge of the Houghton office. Hitherto the interests of the Survey had been devoted mainly to the Northern Peninsula and to structural geology, but the numerous requests reaching the state geologist for information on water supplies, coal, clay, etc., brought about, in a measure, the continuance of investigations of the economic geology of the State, and naturally caused the activities and publications of the Survey to assume a more diverse character.

Field-studies were made of the delta of the St. Clair River and of the gypsum deposits and industry of the State. In the Northern Peninsula, an exploration and reconnaissance along the northern shores of Lake Michigan and Lake Huron marked the beginning of Prof. Russell's active work on the Survey; an examination of the copper-bearing rocks between Bessemer and Lake Superior down to the Black River was made. Dr. Hubbard continued without salary to direct the work of the Survey, but in 1903 found it impossible to devote time to it, and Dr. Frederic W. Wright was appointed assistant state geologist.

Dr. Wright made a study of the Porcupine Mountains and Mt. Bohemia, and towards the close of Dr. Lane's administration, Mr. R. C. Allen began a study of the Iron River district. In addition, Mr. Leverett prepared a report on the surface geology of the peninsula, and Dr. Lane made a study and analysis of the potable waters of northern Michigan and correlated copper drillings from data furnished by the mines.

In the Southern Peninsula, in accord with Dr. Hubbard's plan to secure data on the economic deposits of the State, examinations were made of salt-shafts, peat deposits, the Port Huron oil field, and foundry sands. County investigations were completed in Arenac, continued in Lapeer, Muskegon, Bay, and begun in Wayne. A survey of Alcona County was made at the expense of the County and one of its citizens, Mr. J. H. Killmaster.

The most important contribution, perhaps, to the literature of geology of the Southern Peninsula during Dr. Lane's incumbency is *The Geological Section*, by Dr. Lane and Prof. A. E. Seaman. The section for the Southern Peninsula was made from a careful examination and correlation of well records by Dr. Lane; for the Northern Peninsula, from drill records and personal observations made by Dr. Seaman. The section was published in 1909, a fitting close to Dr. Lane's long and active connection with the Survey.

In securing legislation and appropriations for the Survey, Dr. Lane was not so successful as in obtaining aid in the scientific field. From the amount of work done and the very meagre appropriation ($8,000 a year), one is constrained to believe that much of the work was a "labor of love," perhaps fittingly repaid by the scientific world, but most unsubstantially rewarded by the chief beneficiary, the State of Michigan. Some needed legislation, however, the establishment of the divisions of topographic and biologic surveys, was secured.

In 1901, a contract was signed by C. D. Walcott, director of the United States Geological Survey, and Dr. Lane, state geologist of Michigan, for the execution of a cooperative topographic survey of what is now known as the Ann Arbor Quadrangle. It is interesting to remember at this point that Act 49, 1838, provided for a topographical department, and Act 92, 1844, provided a salary for a state topographer. For the Ann Arbor Quadrangle, $4,000 was to be expended by the Federal Survey and $2,000 appropriated from the meagre general fund of the State Survey. The total was not sufficient to complete the mapping and it was finished at Federal expense.

The satisfactory completion of this map, the demonstrated value of the Menominee sheets (prepared by the Federal Survey), and the repeated endorsements, earnest solicitations, and indefatigable efforts of scientists, scientific societies, and the state geologist, convinced the Legislature of 1903 of the need of such topographic work, and it devoted, therefore, the sum of $1,000 to continue the work. This act was a step in the right direction, but it did not go far enough. The Legislature of 1905, however, by Act 251, authorized the Board of Geological Survey to accept the cooperation of the United States Geological Survey "in the preparation and completion of a contour topographic map of this State, which is hereby authorized to be made." The division has since grown, but during Dr. Lane's administration the Legislature did not see fit to appropriate sufficient funds to carry the work to speedy completion, although the Federal Survey was willing to cooperate.

The original acts creating the Survey included also provision for a biological survey, but with the reorganization of the Survey in 1869, the Legislature made no provision for carrying on the biologic work. As a result, for thirty-six years an important field was neglected. The Academy of Science attempted to remedy the matter. From the year 1900, brief references are made in the Board of Geological Survey to the attempts to reestablish the biological division. Dr. Lane asked for an appropriation of $1,000 "till we can see what the work needs." In 1903, the Board asked Dr. Lane to confer with the biological departments of the Agricultural College and of the University and to submit a plan for the conduct of the survey. The result of these activities was the passing by the Legislature of 1905 of

Act 250, which authorized "a thorough biological survey of the State" under the direction of the state geologist.[2]

The Biological Survey did not lack material for early publications. Ecological studies had been made during 1904 and 1905 in the Porcupine Mountains and Isle Royale. These expeditions had been made at no expense to the State, but had been made possible through the generosity of public-spirited friends of the University Museum, Mr. H. M. Kauffman, Hon. Peter White, and Dr. Bryant Walker.

The prolonged strike of the hard-coal miners in 1902-1903, followed by the scarcity and general high prices of all sorts of fuel, led to consideration of all possible sources of fuel-supply, among them, peat, since about one-seventh of the area of Michigan was estimated to be swamp-land. Dr. Lane prepared a brief report on peat in 1902, and later assigned to Prof. Davis the task of making an extended investigation of peat formations, deposits, and distribution in the State. The resulting report is a classic. The demands for it, resulting in the speedy exhaustion of the edition, and the continued requests, alone prove the wisdom, if proof is needed, of establishing the Biological Survey.

A biologic survey, mainly in the interests of the Fish Commission, was made of Walnut Lake, Oakland County, to determine why whitefish thrive in this particular lake, though unable to maintain themselves elsewhere. Other investigations were well under way for later reports.

[2]This is the first law since that of 1869 in which the words "State Geologist" appear.

An outcome of the organization of the Biological Survey was the forming of an advisory committee for the Survey, an extra-legal body of scientific men known as the Board of Advisers, consisting of two geologists, two botanists, and two zoologists. In 1908, Dr. A. G. Ruthven, of the University of Michigan, was appointed chief naturalist of the Survey.

In 1909, Dr. Lane resigned from the Survey to accept a position in Tufts College, after an association with the Survey of more than twenty years. During this time he had watched the Survey grow from a small department adjunct to the College of Mines, employing part time of a geologist and functioning mainly in the Northern Peninsula, to an independent organization employing a large body of trained scientists, although always sadly hampered by insufficient appropriation.

In September, 1909, Dr. Lane was succeeded by Mr. R. C. Allen. The work of the past eleven years is too well known to justify detailed discussion here, but, in view of the slow growth of the Survey since 1837, the growth of the past decade has been almost phenomenal. The Survey has expanded to include the departments of geology, topography, biology, mineral resources and mines appraisal. It cooperates with the Federal Survey in topographic work and collection of mineral statistics, and also with practically every department of the State government, particularly the Securities Commission, Tax Commission, Highway Department, Public Domain, Department of Health, State Park Commission, Agricultural College. It cooperated, too, with the Ohio Survey in the re-location and marking of the Ohio-Michigan boundary line. Twenty-nine publications have been issued, including eight bulletins on the mineral resources of the State, five biological reports, eight geological studies, two reports on economic geology, three on surface geology and one on drainage. These publications show the diversity of activities directed by the Survey, and their wide extension over the entire State.

Various laws have been passed relating to the Survey. Act 7, 1911, abolished the office of commissioner of Mineral Statistics and transferred his duties to the Board of Geological Survey; Act 341, 1913, created definite connection with the Tax Commission by making an appropriation for the purpose of mines appraisal; Act 373, 1917, authorized the making of a soil survey of the State. Emphasizing again part of the enabling act of 1869, the last act authorized and directed the Survey "to investigate soils and subsoils in their relation to agriculture, and to publish and disseminate this information among the people."

The purpose of the law was approved by Governor Sleeper as witnessed by his signature to the act, but as chairman of the Board of Geological Survey he refused to permit the work to be done.

In October, 1917, the Board of Geological Survey authorized cooperation with the United States Department of Agriculture in a drainage investigation of the State. Every county was investigated by an engineer representative of Drainage Investigation, Conferences were held with each county drain-commissioner; drain records were examined and abstracted and compiled; county officials interviewed; field-trips made and drains investigated. The report was published for the Legislature of 1919, but although a bill to remedy drainage was introduced, the Legislature adjourned without passing the much-needed law.

Much larger appropriations have been secured and wisely expended. In fact, since 1869, the various legislatures have appropriated somewhat more than a half-million dollars for the geological, mineralogical, biological, and topographical survey of the State, of which about half has been appropriated and expended since 1909. It should be noted that a large part of the recent appropriations has been made for the work with the Tax Commission, and the appropriations have been more than justified by the increases added to the State income from taxes through that cooperation.[3]

[3]During the existence of the Survey, the total appropriations and expenditures have been as follows: total appropriations, 1869-1920, $556,935.60; total expenditures, $508,077.59; total appropriations, 1909-1920, including the present appropriation, $250,727.59; total

expenditures after 1909, not including the fiscal year of 1920, $199,534.23.

The Great War did not find the Survey unprepared. Cooperation was given in mapping the Custer area. In the Survey records, the War Minerals Committee of the Council of National Defense found, without special investigation, an adequate source of information concerning those minerals needed, particularly a sand for optical glass. Two members of the staff of 1917 enlisted and saw service overseas, and the director served in Washington as a member of the Board of Tax Reviewers.

After the Armistice, the Survey prepared to go back to more intensive work in the economic field. Upon the return of the staff engaged in active war work and military operations, the routine work of the war period gave way to more precise geological investigations and to plans for expansion. Topographic mapping was renewed so that now about twenty per cent of the State has been covered.

As a result of increased need for competent geologists in post-war reconstruction of the industries of the country, Mr. Allen was made numerous flattering offers by mining interests. In October, 1919, he resigned as state geologist to accept the vice-presidency and general managership of the Lake Superior Iron Ore Association.

On October 28, 1919, the Board of Geological Survey appointed Mr. Richard A. Smith to the office of state geologist, director of the Geological Survey.

In brief review, the Third Survey, organized by law in 1869 to make a mineralogical and geological survey of the State, has been expanded by various acts of the Legislature until now it consists of three main departments: geological, with the divisions of Geology, Appraisals and Mineral Statistics; topographical; and biological. The Survey is housed in offices on the fourth floor of the Capital National Bank Building. It has investigated and is investigating the geology, physiography, drainage, topography, economic resources in metals and non-metals, fauna and flora of the State as well as assisting other departments of the state government, particularly in the appraisal of mines for taxation purposes. "The Survey as now organized occupies a unique position among the similar organizations of other states, because it has led the way in adapting the results of its scientific investigations, as well as the technical ability of its staff, to the practical needs of the State, not only in the development, use, and conservation of our natural resources, but also in the direct administration of some of the important laws. The Board and its staff have seized on every opportunity for useful service, so far as the facilities and funds have permitted."

It has not been possible in this sketch of the history of the Survey to review the work of all the geologists and their assistants, and it has been necessary to neglect entirely the work of many others who have directly or indirectly furthered the work of the Survey. To enumerate them all would be to recall the names of geologists, mineralogists, biologists, topographers, and others connected with the various educational institutions of this and other states, and with the Federal Survey, whose studies have enriched the literature and contributed to the present fund of knowledge of the geology and natural history of Michigan, as well as those private individuals whose generosity and interest in scientific pursuits have made many of the studies possible. All have believed in and sought to make the world see the truth of the motto on the state coat of arms: *Si quaeris peninsulam amoenam, circumspice*."

STATE GEOLOGICAL SURVEY
LANSING, MICHIGAN

# A NEW GASTROPOD AND A NEW CEPHALOPOD FROM THE DEVONIAN OF MICHIGAN

G. M. EHLERS AND R. C. HUSSEY

## INTRODUCTION

An excellent collection of fossils from the Devonian rocks of Alpena and Presque Isle counties, Michigan, was recently presented to the Museum of Geology of the University of Michigan through the generosity of Mr. H. H. Hindshaw. In this collection were found the types of the new species described in this paper. When further examined, it will undoubtedly yield other new and interesting fossils.

## DESCRIPTION OF SPECIES

**PLEUROTOMARIA (?) ALPENENSIS** N. SP.

(Plate XXXVII, Figures 1, 2 and 3)

The only known specimen of this species, which is provisionally referred to the genus *Pleurotomaria*, is poorly preserved; the apertural part of the shell and most of the spire have been destroyed. Certain structures of the specimen are, however, very striking and serve to distinguish it from other gastropods.

The uninjured shell was turbinate, the spire was more or less depressed, and the whorls probably numbered about four. The last whorl, which makes up most of the specimen, is transversely subovate in the section near the aperture. The upper and lower surfaces of this whorl are convex; the convexity of the latter surface is somewhat less than that of the former. The periphery is marked by a narrow slit band with elevated margins. The whorl, at least near the aperture, is thinnest on its inner side. This is indicated in part by the fact that this side easily takes a distinct impression of the lamellose folds or ribs of the lower side of the preceding whorl. The inner lip is considerably thickened and reflexed,

nearly or quite covering the umbilicus. The surface of the last whorl below the slit band is ornamented with well-defined, rounded, revolving ridges or spirals; the one in contact with the lower side of the slit band is somewhat larger than the others.

Crossing the spirals are lamellose folds or ribs, which toward the aperture extend outward as broad, foliate expansions, and become more conspicuous than the spirals. All of the ribs extend upward to the top of the slit band; a smaller number extend above it and are traceable to the top of the whorl. The latter, where they cross two somewhat distantly separated spirals on the upper side of the whorl, are bent upwards and backwards, forming prominent nodes or spines with more or less semicircular excavations on their anterior sides. Some of the ribs, at a few places between the two distantly separated spirals, and at points where they cross a narrow spiral occupying a position just above the upper one of these spirals, are raised into very low nodes with crescentic cavities on their anterior sides. Both large and small nodes are of the type-of the modern gastropod *Fulgur carica*. The surface of the shell is further ornamented with very fine striae, which are parallel to the ribs.

According to Mr. Hindshaw, the type specimen of this species (No. 1261, Museum of Geology, University of Michigan) was collected from the Alpena limestone member of the Traverse formation at El Cajon Bay, Alpena County, Michigan.

**NEPHRITICERAS HINDSHAWI** N. SP.

(Plate XXXVII, Figure 4, and Plate XXXVIII)

The only known specimen of this species consists of the left half of a shell, which is preserved in a fragmentary condition. The apical end of the shell is badly crushed and the living chamber flattened.

The shell is large, coiled in one plane and expands rapidly from the apical to the apertural end. In the uninjured state, it had little more than one volution; the apical end probably was in contact with the dorsal surface of the living chamber near the aperture. At the aperture, the dorso-lateral parts of the shell seem to have extended forward, forming on each side of the shell an auriculate expansion. The contour of the edge of the expansion on the left side is indicated in Plate XXXVIII by a full line, which represents a seemingly uninjured part of the apertural margin and by a broken line, which represents the probable position of the unpreserved part of the margin. The sides of the shell, especially anteriorly, slope rather abruptly toward an umbilical perforation, the width of which is about 26 mm. The cross section of the posterior part of the shell seems to have been more or less subcircular.

The living chamber is very large; its length, measured along the ventral side, is about 168 mm. The camerae increase in depth somewhat regularly from the apical part of the shell to the fifth one posterior to the living chamber. The five camerae behind the living chamber decrease in depth toward the latter; the most anterior one shows a decided decrease in depth with respect to the four immediately behind it.

The septa have an average thickness of about .75 mm. The sutures on the lateral slopes of the shell are nearly straight except for very broad, ill-defined lobes.

The shell is ornamented by very conspicuous, rounded, revolving ridges, which gradually diverge from the apex to the aperture. The tops of these ridges near the posterior, crushed end of the shell are distant from one another about 2 mm., and near the aperture about 10 mm. The ridges on the ventral side of the shell have been brought close together by compression. On the lateral slopes toward the aperture, the ridges become flatter and broader. This seems to be due to solution, and to the flattening to which the anterior part of the shell has been subjected. Well-preserved parts of the outer surface of the shell are ornamented with very fine, transverse striae, which undoubtedly covered the entire surface.

The average thickness of the shell is about 1.75 mm. The shell is about one and one-half times as thick in the revolving ridges as in the interspaces. A maximum thickness of 3 mm. was noted in the ridges on the lateral slope near the posterior part of the living chamber. Towards the aperture, at least on the lateral slopes, there is a thinning of the shell, which seems to be the result of solution or compression.

The type specimen is of interest in that it shows old age characteristics, such as the auriculate, forward expansions of the shell and the decrease in depth of the camerae behind the living chamber.

This species somewhat resembles *Nephriticeras liratus* (Hall) from the Devonian of New York State, but differs from that species chiefly in having a smaller number of volutions, a less rapid expansion of the shell, and a wider spacing of the septa.

The holotype of this species (No. 7530, Museum of Geology, University of Michigan) was collected by Mr. Hindshaw, in whose honor the species is named, from the Long Lake member of the Traverse formation in Sec. 7, T. 34 N., R. 5 E. (about four miles north of Hawks Post Office).

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## EXPLANATION OF PLATES XXXVII AND XXXVIII

PLATE XXXVII

**Pleurotomaria** (**?**) **alpenensis** n. sp. (Figures 1-3)

Fig. 1. Lower side, showing spirals, ribs and reflexed inner lip.

Fig. 2. Side view, showing slit band and prominent spines on the upper side of whorl.

Fig. 3. Upper side, showing spines located on two widely separated spirals.

All of these figures are natural size.

**Nephriticeras hindshawi** n. sp.

Fig. 4. Side view, showing preservation and ornamentation of shell. X 1/2.

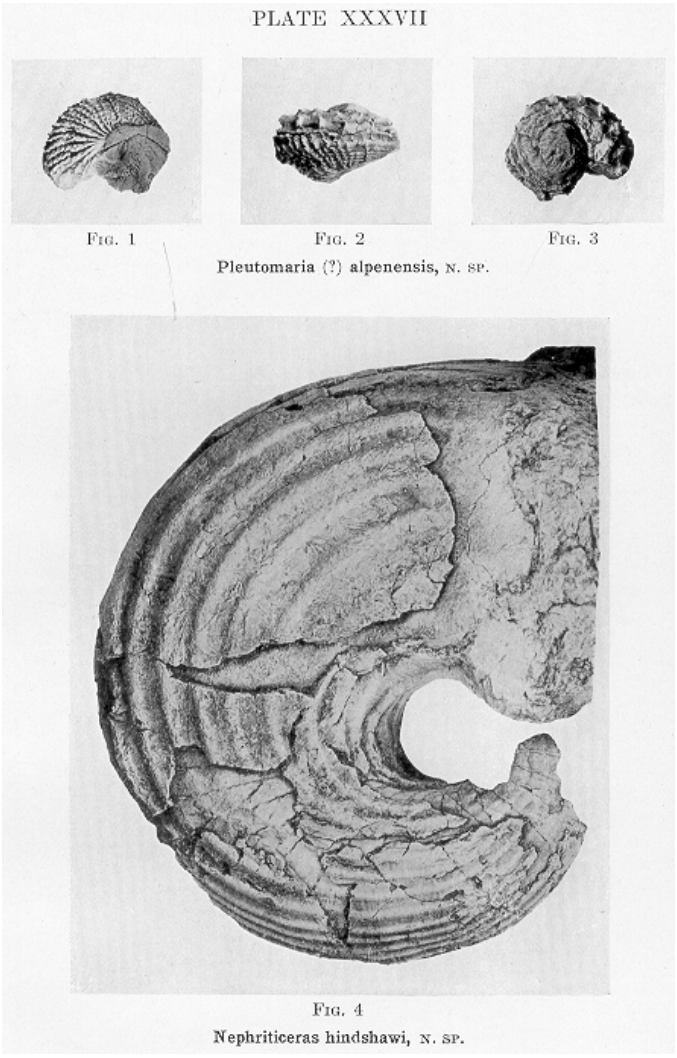
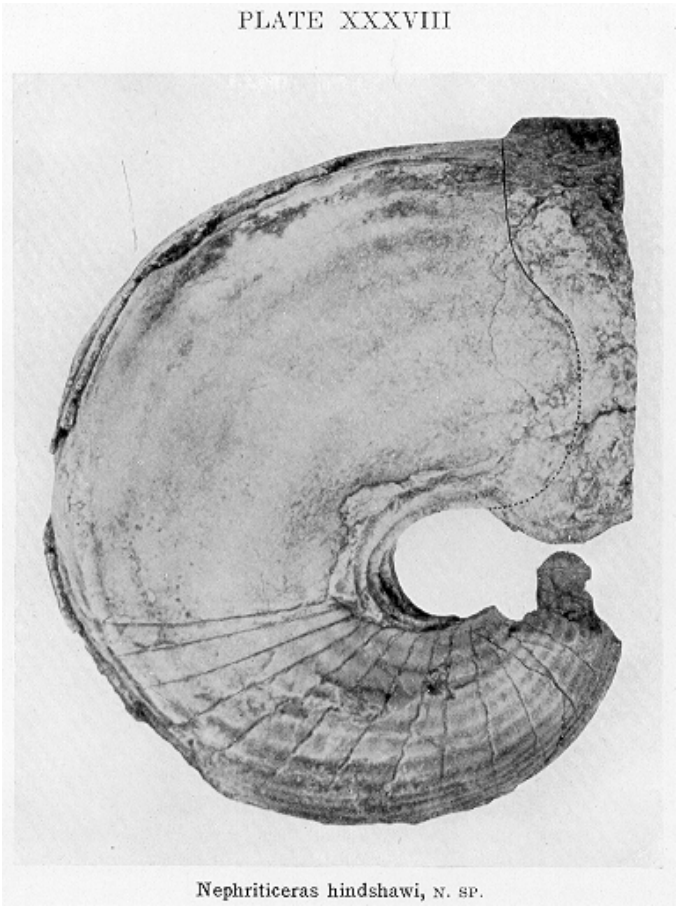



PLATE XXXVIII

**Nephriticeras hindshawi** n. sp.

Side view of specimen with portions of the shell removed, showing sutures, depth of living chamber and camerae, and probable contour of the auriculate forward expansion of the shell. X 1/2.



# THE SOUTHWESTERN MICHIGAN METEOR OF NOVEMBER 26, 1919[1]

WILLIAM HERBERT HOBBS

## INTRODUCTION

In the early evening of November 26 (Thanksgiving Eve), 1919, a meteor was observed from many points throughout Van Buren, Berrien and Cass counties in extreme southwestern Michigan, and at one or more points in the encircling counties of Allegan, Kalamazoo and St. Joseph in Michigan, and at St. Joseph, Elkhart and Lagrange in Indiana. In addition, it was reported from several more distant points, viz.: near Wewaka in Noble County, Indiana; Albion, Adrian, Saranac (Ionia Co.), Mason (Ingham Co.), Muskegon, Croton (Newaygo Co.), Ludington, and Thompsonville (Benzie Co.), all in the Southern Peninsula of Michigan. From three quite remote points also it was reported; Milwaukee across Lake Michigan, Newberry in the Upper Peninsula of Michigan about fifty miles northwest of the Straits of Mackinac, and at Lucknow in Ontario.

[1]This paper was read also before the American Philosophical Society at the annual meeting in April, 1920.

In the *Grand Rapids Press* of November 27 (Thanksgiving Day), a semi-sensational, semi-humorous account of the meteor was published under the head, "METEOR FELL IN LAKE OR THERE WAS QUAKE, AURORA WENT ON SPREE OR — SOMETHIN' HAPPENED." Friday morning, November 28, the *Chicago Tribune*, which circulates within the district in which the meteor was widely reported, carried the head "METEOR THAT ROCKED STATE IN LAKE, BELIEF," and the *New York Times* carried on the front page a Detroit despatch headed, "HUGE METEOR FALLS INTO LAKE MICHIGAN." A statement attributed to the lighthouse attendant at Grand Haven, which appeared in the last two papers, is as follows:

> What looked like a ball of fire appeared to fall in the lake about fifteen miles south of me, I thought it was a falling star. I could hear it whistle during its terrific rush toward the water. When it seemed to strike the water, a flash of flame shot in the air and caused a great disturbance.

This report was copied and carried by many papers of later date, especially by weekly country papers. When the writer first visited the region about a week later, the effect of the impression from reading this account was so general that it was in many cases difficult to secure correct independent reports of what each observer had himself seen. Examination into the original report from Grand Haven, no less than the broader investigation as a whole, soon convinced the writer that the meteor, or at least a portion of the original mass, must have fallen upon the land.

On December 4, the writer sent out a questionnaire addressed to editors of newspapers published in southwestern Michigan and in northwestern Indiana, some forty-five in all, and in addition to superintendents of schools in twenty-six of the larger places of the district. Within a week after the fall of the meteor, he visited points in Van Buren County, and later made trips to other portions of the district. The newspapers gave publicity to the questionnaire, and an extended correspondence developed with eye and ear witnesses throughout the district. Their testimony forms a large part of the basis of this report.

Mr. C. F. Schneider, the very able meteorologist in charge of the Weather Bureau station at Grand Rapids, early took a lively interest in the investigation and independently assembled reports from observers at the Michigan stations of the Weather Bureau. These reports are of great value and have been kindly placed at the writer's disposal. A request for information about the meteor which had been addressed to the Department of Marine at Ottawa by Mr. Alfred Cooper of Beaconsfield, Bucks., England, was by that department referred to the Inspector of the Twelfth District of the United States Lighthouse Service, and was the starting point of further assembling of data from observers in that service. This valuable information also has been placed at the writer's disposal. Acknowledgments are due especially to Mr. Schneider and to Mr. N. M. Works, the first assistant superintendent in the Office of Inspection of the Lighthouse Service at Milwaukee.

So far as is known, the meteoric stone which fell at Allegan in southwestern Michigan in 1899, is the only other fall of a meteorite which is upon record for the State of Michigan.[2] In addition there are two "finds" on record. These are the Grand Rapids iron of 51.9 kilograms found in September, 1883, in the course of excavations in that city; and that of Reed City, an iron weighing 19.8 kilograms, which was found in September, 1895, on a farm near that place in Osceola County.

[2]George P. Merrill and H. N. Stokes, *A New Stony Meteorite from Allegan, Michigan, and a New Iron Meteorite from Mart, Texas, Proc. Wash. Acad. Sci.*, 2:41-68, 1900. See also *Bull. 94, U.S. Nat. Mus.*, p. 21, Plate VII.

## THE APPEARANCE OF THE METEOR

Had the evening been clear, the meteor would undoubtedly have been visible over a wide area as a brilliant body having a definite form and leaving behind it a definite train. The weather throughout the region of its near approach to the earth was either cloudy or rainy, so that its appearance took on generally the character of a sudden brilliant illumination, which was described by many as resembling heat-lightning.

It may at first appear strange that the best observations were rather generally made at positions remote from the place of near approach to the earth's surface. This is due to the fact that from these points the object was seen at a great height, and along a line of direction which was above and clear of the low rain-clouds into

which it later disappeared. Those rare observers who were nearer, and who also sensed the moving meteor as a "ball of fire," either got fortuitous glimpses through a rift in the clouds, or were so near the body when it reached the earth as to see it even through the fog.

After the general area of the probable fall of the meteor had been roughly determined, there occurred a heavy snowfall, so that a suitable opportunity of searching for the body did not arise till the following summer. Such search as has been carried out during two brief trips to this area has served only to make it improbable that it will be found except by mere accident, since a large part of the area is swampy, or wooded, or else has been plowed over. The hope that the body might be found is in part responsible for the long delay in assembling this report.

## OBSERVATION OF THE METEOR AS A "BALL OF FIRE"

The following observations of the meteor as a definite form, rather than as an illumination or as a flash of light, were made in Michigan:

*Newberry, Luce County*

A very brilliant meteor was seen about eight o'clock on the evening before Thanksgiving in a position about southwest when first noticed and considerably above the horizon, though relatively low. Its course was southeastward and downward at a point south by about 9° west near the horizon. It burst like a rocket and sank from view, all in a few seconds. The hands of the observer, A. L. Harter of the Newberry State Hospital, were held about thirty-eight inches apart to show how big it looked. — Reported through Meteorologist Schneider.

*Ludington and Point Sable*

A brilliant meteor was seen by watchmen at the Coast Guard stations of Ludington and Point Sable at 7:45 p.m. on the twenty-sixth. It was first seen almost overhead, whence it moved to the south, leaving behind a trail of blue. When near the southern horizon, and apparently along the lake shore, it burst like a sky-rocket into many pieces, which were colored blue, red, green and yellow and otherwise, and fell to the ground. A swishing was heard as the meteor passed through the air; no explosion and no shock were felt. — Reported through Meteorologist Schneider.

*Thompsonville, Benzie County*

Richard Emmons, a thirteen-year-old boy, going home "about 7:45 saw a ball of fire as large around as a stove fall from near the top of the sky and soar southward to the ground. It made the night as light as day." — Report in *Thompsonville News*. To the writer the boy reported that the meteor was seen about 7:45 p.m. and was in view about four seconds. It was colored blue and white. No sound was heard.

*Muskegon*

Mr. and Mrs. A. W. Gunn, city-editor and society-editor respectively of the *Muskegon Chronicle*, with their daughter, Mrs. W. V. Johnson, of Traverse City, were on the street facing south with a clear view of the sky. "They state that the entire sky was at first lighted with a brilliant blue light. Then through a small rift in the clouds they witnessed the meteor. . . . The larger meteor appeared to be as large as the moon. The second part, which closely followed and apparently in the same path, was much smaller. The occurrence was at about 7:45 p.m." — *Grand Rapids Press* and *Muskegon Chronicle*. The meteor was also reported as appearing to strike south of the city, but no explosive sounds were heard.

*Grand Haven*

"E. B. Wright, coast-guard, states that the meteor was travelling due south, passing directly over his station, and that it apparently fell upon land on or near Rosy Mount (a great sand-dune near the lake shore), about four miles south of his post of duty. As it passed above him, he was in position to ascertain the direction with considerable accuracy. The principal luminous center resembled the moon and was closely followed by a smaller one. The flash lasted probably ten seconds and no sound was heard. The light was of a bluish-white. There remained a long streak somewhat like the tail of a comet for about fifteen seconds after the meteor had disappeared." — Keeper's report to the Lighthouse Service supplied by Supt. Works.

Mr. W. E. Dodge, radio operator at this place, reported a meteor "with two centers, first like the moon, second smaller."

All the observations recorded above were made at points distant from the region of rather general observation within which the meteor was described as a bright illumination and as accompanied by various sounds. They are rather consistent in their indication that the direction of the meteor was to the southward of the observer, and that no accompanying sounds were heard. They are also generally consistent in describing the direction of movement of the body to be from some point above the horizon downward toward the horizon.

Observations made within the region of near approach to the earth's surface are equally consistent in showing that the movement of the meteor was from the southeast toward the northwest. This apparent discrepancy is susceptible of simple explanation. The remote observers to the northward, all of whom saw the meteor as a definite object, were under a clear sky, and the meteor was observed as it entered the atmosphere at a great height. Even though the object had been approaching them, if it came to earth far to the southward, it would give the effect of a body moving in the opposite direction, or toward the southern horizon. As a consequence of the clouds, fog, and rain which generally prevailed, only the illumination was seen, except in the case of the very few persons who happened to be very near to the meteor when it came to earth.

I am indebted to Professor C. F. Schneider for the meteorological data which appear upon Map II (See page 259), and which apply to the hour of 8 p.m. on November 26, within a quarter of an hour of the time of the meteor's fall.

The persons who observed the meteor at Muskegon stated positively that the object was seen through a rift in the clouds. This locality is obviously near the boundary

of the clear sky. Ludington reported that low down in the sky near the horizon the meteor burst like a rocket. As we are to see, both the light and the sound observations within the district of near approach to the earth afford confirmation of this view.


Map II. Light Phenomena observed in connection with Fall of the Meteor of Southwestern Michigan on the Evening of November 26, 1919.
The sky and weather indications are of 8 p.m.

The observations which follow differ notably from those outlined above, and they are believed to indicate that the observers were relatively near to the place above which the meteor broke up and fell:

*Four Miles S. S. W. from Dowagiac*

Mr. L. L. Hamilton, undertaker at Decatur, while driving in a Ford car on the east road from Dowagiac to Niles, observed the meteor when he was going west on Townline Road near the house of Charles Stretch,

"I was frightened by a white light touched with green and by flashes that were at least ten or fifteen seconds displayed. A big ball of fire which looked as big as a balloon disappeared in the woods in front of me. When this occurred, I at first let go of my steering wheel, pulled up on my clutch, and stopped. It seemed as though I was stunned and could not stir. I did not hear a very loud sound — only a jar — as my engine was running. I regained my senses, the light disappeared, and I resumed my journey. I could not see anything in the woods, but noticed an odor like sulphur burning. When I arrived at the house of a friend two miles this side of Niles and reported to them what I had seen, I learned that they had seen the same light, though not so intense and bright. This happened about eight o'clock. I should judge that the body took a plunge into these big woods. It came from the southwest going northwest. All was lighted up like day in the direction of the woods for a few seconds, and feeling sure my machine was on fire, I made an attempt to get out and see. By the time I had regained my senses and gotten one foot on the running board, it was all dark except for the light of my machine ahead. Of course, what I saw was through the glass toward the open facing these woods. The movement of this huge fire ball was very slow; it seemed to explode, and leave a fiery tail behind."

Mr. Charles Stretch, near whose house this happened, was interviewed by the writer. He had been at the time in the house, and had seen the meteor, which appeared to him as a flash, but the sound followed immediately. Other reports from persons within houses nearby given to the writer, were likewise that the sound here followed immediately after the flash.

*On Dixie Highway, Three Miles South of Dowagiac*

Mrs. Hiler, who lives on the Dixie Highway at this point, reported to the writer that she was in her house at a window facing south and saw the meteor as a definite body in a direction a little west of south (this direction I confirmed with compass from her indications). The meteor was observed very low down near the horizon, at a point where are the woods in which Mr. Hamilton reported seeing the meteor fall, though from nearly the opposite direction. Mrs. Hiler reports that the meteor appeared to burst and go to pieces "like a rocket," and that a rumble was heard "almost immediately afterward."

*Athens, Calhoun County*

William Hutchins at about 7:30 p.m. saw what he described as a bright-red round object like a shooting star, but the size of a common tea kettle, "move over him going from east to west at an angle of about 45° or less above the horizon. A streak of fire followed it."

## APPEARANCE OF THE METEOR AS A FLASH OR ILLUMINATION

Such observations were very general throughout the region of southwestern Michigan and the adjoining parts of Indiana. The points at which the flash has been reported are entered upon Map III (See page 262).

A few of the more interesting observations selected from among many are given below. Since the place of fall is believed to have been near the post-office of Pokagon, the location of these points is sometimes indicated with reference to that locality.

*Centerville, St. Joseph County*

"Very bright-yellowish light suffused the clouds and seemingly every particle of the cold, misty rain that was falling. The road, trees, houses, and even ourselves were bathed in a blinding phosphorescent-like glow which had its center in a bright streak in the sky above us. It passed over us toward the west. Immediately came a muffled report or jar that shook houses and the very earth like an earthquake." — Statement of Leroy Milhan, highway construction superintendent.

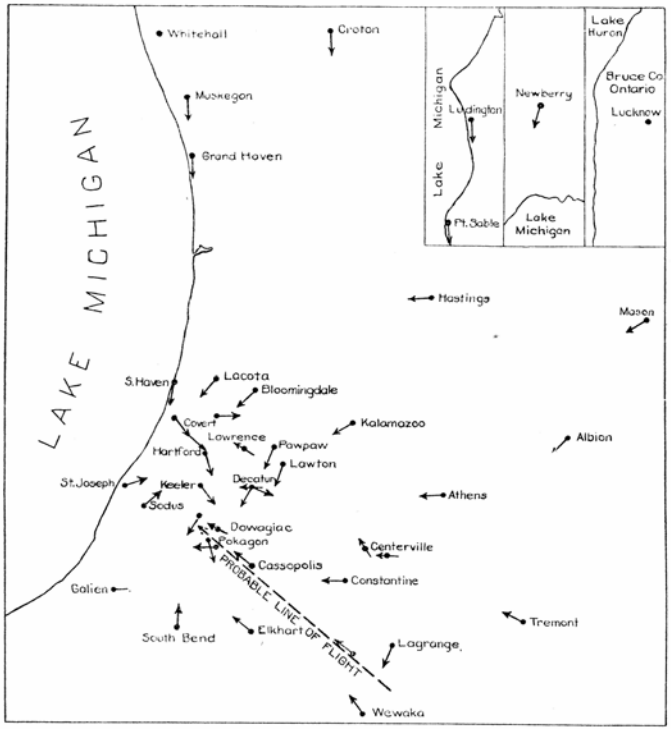
*Lawrence, Van Buren County*

Lawrence is about 18 miles northwest of Pokagon. A farmer and his wife, who were in the field looking after cattle at a point one mile east and one mile south of the village, report as follows:

"It was very dark and all at once the heavens and the horizon were lighted up, and everything was a shimmering green for a period of two minutes or more. I turned, I recall, and looked at the neighbors' houses in the distance by this light; and then suddenly the green light turned to red and stayed red for at least a minute. The green and red lights were not blended — the green was distinctly green and the red was red."

*Notre Dame, Indiana*

Notre Dame is just over the state line and about fifteen miles south-southwest of Pokagon. The dean of Notre Dame University reported on the basis of observations by students who were on the campus, that there were two distinct flashes seen to the northward and that these were one or two seconds apart. C. A. McAllister reported through him that the first flash was green and the second orange-red. Others said that the light was very bright and like that from an electric battery.




Map III. Sketch Map showing Places Where the Meteor was observed near its Place of Fall.
Arrows transecting the points indicate observed directions of flight. Arrows going out from the points show the direction from the observer in which the phenomenon was seen.

*Three Oaks, Berrien County*

At this point the flash as observed by Mr. Savage was greenish-blue, and afterward the western sky was lighted up with a red glow.

Since the color effects were a very striking feature of the phenomenon, and since observations made at widely separated localities show a considerable measure of consistency, it has been thought best to incorporate here a summary of observations reported from different localities:

Athens. — (a) Reddish (Hutchins); (b) bluish, like electric spark (McMillan).
Bangor. — Bright red.
Cassopolis. — Light, followed by red.
Decatur. — Greenish, turning to light red.
Elkhart (Ind.). —Blue flash.
Grand Haven. — (a) Bluish-white (Wright); (b) bluish-white at first, after which the clouds were suffused with red (Dodge); (c) reddish glow (McConger).
Grand Rapids. — Bluish-green, about color of northern lights.
Hartford. — (a) First greenish-yellow, then different colors (Olds); (b) tint of blue, might have been green (C. A. Boss); (c) greenish-blue (first in south), then rose color to northward and extending only half way to the zenith (Finley).
Kalamazoo. — (a) Deep pink in northwest at first, then spread all around (Robinson); (b) first dazzling white, changing to orange and blue (Browne).
Lagrange (Ind). — Red.
Lawrence. — Everything a shimmering green for two minutes or more, then suddenly the green light turned to red and stayed red for at least a minute.
Muskegon. — Brilliant bluish light at first.
Pokagon. — Very bright white, and blue and tint of yellow.
South Haven. — White.-
Three Oaks. — (a) Such light as is made by an electric wire burning out (Fox); (b) flash greenish-blue and afterward western sky was lighted up with red glow (Savage).

## IMPRESSION OFTHE CONCUSSION

The following variations of the impression received of the shock have a collective value:

Athens. — Jar like heavy thunderclap.
Allegan. — Faint jar.
Centerville. — Jar which shook houses.
Covert. — As though something had struck roof, it jarred the house.
Elkhart (Ind). — Shook house.
Lawrence. — Jarred window-sills and doors.
Pokagon. — Jarred Ford car with engine running.

## INTERVAL BETWEEN FLASH AND FOLLOWING SOUNDS AS A MEASURE OF REMOTENESS FROM OBSERVER

Except in the vicinity of Pokagon, near where it is believed the meteor broke up, a distinct interval measured in considerable fractions of a minute or several minutes was observed to separate the time of the flash from that of the following sounds. In most cases the values given are rough estimates only. In several instances, however, observers had the good sense when the sound was heard, after walking a certain distance since observing the flash, to retrace their steps watch in hand, and so fix the interval with considerable accuracy.

It is noticeable that there is an increase in the length of the interval, in proportion as the observing points are distant from the neighborhood of Pokagon, toward which other indications point as the place of fall. At Pokagon Post Office, on the Dixie Highway, north of this point, and at Summerville about one and a half miles west of Pokagon, the sound resembling thunder is reported to have followed close after the flash. At Dowagiac a man

was on the street and saw the flash come almost exactly from the southeast. The sound resembling thunder followed after he had walked a block — probably about a minute.

Near Indian Lake, a little over five miles west of Dowagiac, people living at "Gilbert Castle" noticed the flash from within the house, and after a "two-minute interval" heard the sound. North of this point to Sister Lakes, Sutherland and Forest Home, practically the same report was received throughout, and the close correspondence produced the impression that this interval had been rather generally adopted for the district as a result of discussion, perhaps at the corner grocery. At Berrien Center, about five miles west of Pokagon, the flash was generally reported, but no sounds were heard. At Fairland, about the same distance west-southwest, neither the flash nor sounds appear to have been noted.

At Galien, about fifteen miles west-southwest of Pokagon, the time between the flash and the rumbling sound was estimated at one and a half minutes. At Notre Dame, just over the state line in Indiana and about the same distance away, the estimate of this interval was "slightly more than minute."

At Three Oaks, twenty miles southwest of Pokagon, a man and his wife were walking toward their home. Through Mr. G. R. Fox, director of the Chamberlain Memorial Museum, they report that the flash was seen when they were on the street. They then walked a distance of three blocks to their home and were just entering when they heard a noise like distant thunder. This interval they estimate at three minutes.

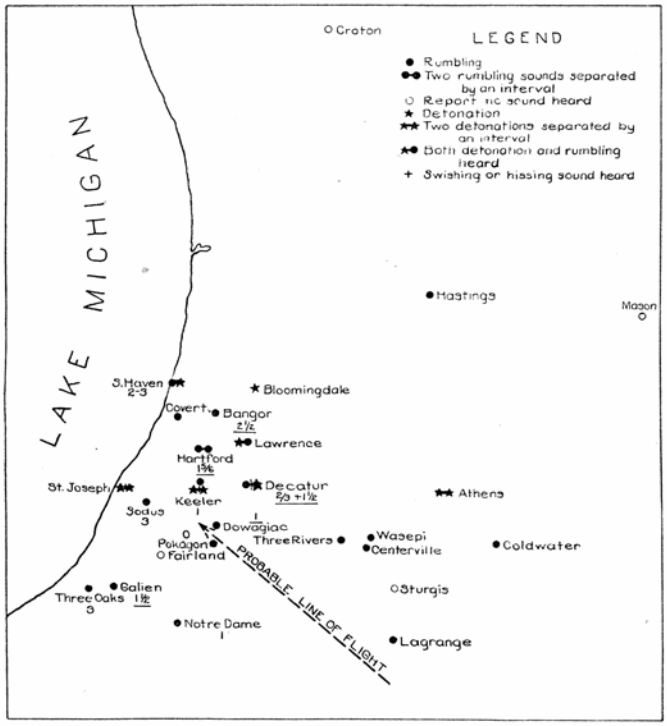
At Decatur, about fifteen miles north-northeast of Pokagon, Mr. Brigham, while walking on the street, accompanied by his wife, saw the flash. After continuing a certain distance, he heard the rumble, and after another interval a sound resembling an explosion, which appeared to come from the south. They retraced their steps, watch in hand, and determined that the first sound arrived about forty seconds behind the flash, and the explosive sound ninety seconds after the rumbling.

From Hartford, about twenty miles due north of Pokagon, we have especially valuable data secured by Mr. C. A. Boss, the school superintendent. He noticed the flash and walked a distance which he twice checked by walking at as nearly the same speed as possible. The average time derived for the interval is two minutes and fifty seconds, with a probable error of only five seconds. The direction of the sound appeared to be south, possibly 20° or 25° east of that direction. There were "two distinct booms like the reports from a heavy gun, close together, but perfectly distinct, not blurred." Two sounds close together were generally reported from Hartford and its vicinity.

Near Keeler, about twelve miles north of Pokagon and five miles south of Hartford, a truck-driver with a gang of five men was halted with his truck stuck in the mud. All observed the meteor flash as a very striking phenomenon, and the estimate which they give for the place of fall is "two minutes away and a little to the east of south." Two detonations were heard and also "a hissing like a fuse burning."

At South Haven, some thirty-five miles north of Pokagon, Theron Kenneda, a coast-guard of the local station, saw the flash and a minute and a half later, according to his estimate, heard the rumble. Another observer at this place estimated the interval at from two to three minutes. It is quite evident that unless the estimate has been checked by some method, as by the time required to walk a certain distance, it does not have great value. For this reason, on Map IV we have underlined those estimates which have been checked in this manner.

At Bangor, about twenty-five miles north of Pokogan, a valuable estimate was made and checked in the following manner. A gentleman was on a train approaching the station from the north. When the train was on the trestle about a thousand feet from the station, the flash was noticed. He rose from his seat in the parlor car, walked through the short train, and as he was descending the steps of the station heard the rumble. Upon this basis, the estimate of the interval was two and a half minutes.




Map IV. Sketch Map showing the Nature and the Distribution of the Reported Sounds in connection with the Meteor.

The figures in connection with certain localities record the estimate of the time interval between observation of the flash and the succeeding sounds. Those underlined are based upon distance walked during the interval, and they have a correspondingly increased value.

## THE NATURE OF THE SOUNDS

The sounds which were described as accompanying the fall of the meteor were of three general types, namely: (*a*), rumbling, described generally as resembling thunder and explainable upon the same basis, the closing of the vacuum behind the moving body; (*b*) detonations, generally described as explosions or as the report from a big gun, dynamite, etc., and explainable as the result of the bursting of the meteor from pressure upon its forward surface, aided by the strains set up between the highly heated front and the cold interior; (*c*) whistling, described as hissing, sizzling, burning of fuse, escaping steam, etc., believed to be due to the rapid projection of meteor fragments after the break-up of the body.

The area within which sounds were heard, and the nature of the sounds perceived at each place, have been entered upon Map IV (See page 267). The hissing sound was reported from Decatur, Keeler, and St. Joseph, all in front of the supposed place of break-up near Pokagon. At Keeler and St. Joseph, two distinct detonations were made out. At Decatur, while but one detonation was perceived, it is interesting to note that this occurred ninety seconds after the rumbling. It is also worthy of note that the sounds were generally perceived for greater distances north and west of the supposed place of fall than in the other quadrants, particularly the south and west.

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# OIL DEVELOPMENT IN MICHIGAN AND THE ANTICLINE AT SEUL CHOIX POINT

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The recent oil "strike" near Deerfield in Monroe County has caused a wave of interest in the oil and gas possibilities of Michigan. Inquiries are coming to the Geological Survey not only from every part of the State, but from nearly every part of the country. According to reports, exploration companies are being organized at Blissfield, Lenawee County, and at Shasburg and Dundee, Monroe County. The Deerfield Oil and Gas Company is already beginning its second test, and exploration projects are being considered in several other places in the State.

This summer promises to be the greatest period of "wildcat" exploration that Michigan has ever experienced. Oil at four to six dollars gives alluring possibilities to the numerous small oil wells drilled at Port Huron, Saginaw, Allegan, and in Monroe County in the days of fifty-cent oil, and also to the many showings of oil encountered in many other tests. Several wells at Saginaw and Allegan yielded from one to five barrels of oil, but with oil selling at fifty or sixty cents, profitable operation was out of question. Small wells have been pumped at Port Huron for many years, but it was due to their very shallow depth that they could be operated at all.

With oil selling from five to ten times the price in 1912, small wells are no longer looked at with contempt by the oil producers. The big oil companies are systematically drilling up their "lean" oil territory formerly not considered worth development. In Pennsylvania, old properties are being re-drilled on the expectation of an average yield of only a barrel a day, and many of these old properties are being profitably operated where the average daily production is only a few gallons of oil.

There are several localities in the State where conditions appear to offer possibilities. At Port Huron, there is a well-defined fold or anticline only partly tested. The depth to the oil formation is only about 600 feet. The structure, coupled with the fact that there are already over thirty small oil wells in this field, invites further exploration.

In Monroe and Wayne counties, the rock strata are warped, and since the "Trenton" formation is known to contain a number of oil-producing "sands," the southern part of the State offers definite oil possibilities in a number of places.

A fold or a structural bench is indicated at Saginaw. Some oil was struck on this structure and further exploration to the north might result in the discovery of much larger quantities. Two or three wells at Allegan produced from one to five barrels of oil at a depth of less than 1,300 feet. There is an anticline near Niles. The Trenton, in the southwestern part of the State, is not excessively deep. The Niles anticline appears to be the most favorable place for exploration, particularly since showings of oil have been found in some of the formations above the Trenton. A marked anticline fold occurs on Stony Island, Detroit River.

Another one appears to lie in the vicinity of Wyandotte. A broad, indefinite fold lies between Algonac, New Baltimore and Mt. Clemens. Discordant dips of the rock strata are present in Monroe County and a broad, low anticlinal fold lies between Pontiac and Adrian. In the extreme southeastern part of Michigan, the "Trenton" limestone is only about 1,600 feet in depth. The depth increases to the northwest, but the Trenton is accessible in a considerable part of the region along the southeastern portion of the State.

An apparently pronounced anticline occurs in Seul Choix Point, but no detailed field work has been done to determine its extent or importance. The Trenton is at relatively shallow, depths along the northern shore of Lake Huron and Lake Michigan, in most places being less than 1,500 feet in depth. At Seul Choix Point, it is probably less than 1,200 feet to the Trenton. This formation is known to contain oil in small amounts, and possibly exploration along the northern shore of Lake Michigan and Lake Huron might result in the discovery of commercial pools.

The Seul Choix Point, Schoolcraft County, projects southeastward into Lake Michigan for about three miles. Apparently, it owes its existence to an upward folding of the rock strata. The direction of the fold is northwest-southeast in line with the general direction of the Point. It plunges to the southeast at a low angle.

Massive beds of the Guelph (Racine) dolomites lie upon the southeast and the northwest sides or limbs of the folds, and the more thinly bedded Manistique dolomites being exposed along the crest. The dip of the Guelph beds is about 6° or 7° on the south limb and somewhat less on the north limb. The dip of the Manistique beds is much less, ranging from 1° to 5°. The interior of the Point is thickly wooded and the rock is concealed nearly everywhere; hence the extent of the structure to the northwest is unknown and probably can be determined only by the drill.

The Seul Choix anticline appears to be of sufficient size and height to influence the accumulation of oil in underlying formations. There is a possibility that the structure is due to deposition of the beds about coral islands in Niagaran seas. In such case the anticlinal dips observed in the Niagaran strata do not extend to beds lying deeper. The evidence is not conclusive and the conditions cannot be definitely determined in advance of the drill. The relatively steep dips and the character of the Guelph beds, however, indicate that folding has occurred to a greater or less degree, and that the structure is in part a true anticline.

The Niagaran limestone group on Seul Choix Point is probably from 600 to 700 feet thick. No wells have completely penetrated the formation in this region and the thickness can be only approximated from field observations; hence the thickness may be somewhat less than the minimum, or even greater than the maximum.

A heavy series of shales and shale-like limestone underlies the Niagaran limestones and overlies the Trenton limestone. The latter is a producer of oil and gas in Ohio, and is known to contain oil in small quantities in both the Southern and Northern peninsulas. Near Deerfield, Monroe County, oil has been struck recently in apparently commercial quantities. It is possible, if not probable, that oil may be found in the Northern Peninsula and structural conditions indicate that the immediate vicinity of Seul Choix Point would be a favorable place for testing out the oil possibilities. The depth to the Trenton is relatively shallow. On the extremity of the Point it is probably not much greater than 1,200 feet and may be considerably less. To the northwest, the depth should gradually decrease.

Most of the State, however, is wholly "wildcat," and the risks incident to "wildcat" exploration, especially in Michigan, appear to be very high. This is a point which every prospective investor in "wildcat" enterprises should hold firmly in mind. Geological considerations indicate that, while Michigan may never become a great oil-producing state, scattered pools of oil will probably be discovered.

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