WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

ERNEST F. BEAN, Director

BULLETIN NO. XLVI — ECONOMIC SERIES NO. 21

MINERAL LANDS

OF

PART OF NORTHERN WISCONSIN

BY

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WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

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PART II

MAPS AND DETAILED DESCRIPTIONS OF TOWNSHIPS

Arranged with southernmost township first, and succeeding townships to the north in order with easternmost first.

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FIGURES

OUTLINE OF REPORT

This bulletin presents the findings of the survey of an area not covered by any other publication, and in which no previous geological work of a detailed and very little of even a reconnaissance nature had been done. The field work was carried out in 1915 in response to a general feeling that there might be iron formation in the heavily drift-covered region. This attitude was expressed by both the companies organized to explore with diamond drills, and by the large lumber companies which, having harvested the merchantable timber, were reluctant to relinquish the mineral rights in selling lands to settlers that followed the logging operations. For a time the issue of preliminary maps and reports on the survey met this demand for information and conferences in the office in Madison discussing the greater details satisfied the more interested parties. Inquiries then decreased in number and the essential service to the public had been accomplished without publication.

In more recent years, interest has evidently been reviving, inquiries have become more numerous, and it appears that these can best be met by publication. Accordingly, the bulletin has been issued. It should be borne in mind that in the elapsed years, the cultural landscape has changed in many localities within the area. For example, new roads have been constructed, new settlements have sprung up, and older ones have grown. Railroads, principally those operated by logging companies, have been abandoned in some places, and others have been built. Accordingly, those examining the accompanying maps will no doubt discover discrepancies. However, the primary purpose of the volume is to make public the geology of the region, and the ideas herein expressed are based on facts of observation to which little has been added in the years that have elapsed since the survey was made.

One outstanding value in the report is the presentation of the magnetic attraction of the area. In the Lake Superior region in general, geologists and engineers have come to look with interest upon the magnetic anomalies as best indicators of the promise of iron formations. In a drift-covered region in which outcroppings of bed rock are rare and widely scattered, the magnetic method is probably the only one that can give a clue to the general character of the bed rock. On the general map and on individual township plats the results of the magnetic work are shown.

In addition to the results obtained by the survey, there are included the results of diamond drill explorations at many points. These explorations were made both in areas covered by this report and in that reported upon in Bulletin XLIV of this survey. These results were provided by the individuals or companies concerned and constitute a valuable contribution for which the Survey is grateful.

The area covered by the report embraces twenty townships which fill in and otherwise supplement the area of the general map in Bulletin XLIV. For this reason the map of the earlier publication has been reprinted with the new areas included. As may be seen from Figure 1, this more nearly completes the survey of the great drift-covered area of Northern Wisconsin south and west of the long known iron ranges of Wisconsin and Michigan. Some gaps still remain and with increasing interest in iron ore possibilities of the region, the Survey aims to meet the demands for information.

The report follows practically the same outline as that of Bulletin XLIV to which, in fact it is largely supplementary. Part I is devoted to general chapters on the geology of the general area. Part II is a compilation of detailed reports on the individual townships.

Chapter I is introductory in nature and gives a general discussion of the purposes of the work, field plans, and a statement of the area covered. In Chapter II the field methods and organization of the work are discussed in detail. Chapter III is devoted to the general geology and gives a generalized statement of the rock formations found and their structure and relations, the details of which are presented more fully in Part II. This chapter discusses in a connected manner the indications of iron formations which are given in Part II. The general physiography of the area is also described in this chapter.

The details of magnetic surveys of the kind made in this area are given in Chapter IV with an explanation of the instruments used, the interpretation of observations made with them, their capabilities and their limitations. This is a reprint of Chapter IV of Bulletin XLIV which has come to be accepted as the only manual on magnetic surveying. The supply of that bulletin has been practically exhausted largely because of the demand for this particular chapter.

Chapter V outlines the basis upon which the lands were divided into classes and gives the reasons for believing that ore may or may not be discovered here.

Chapter VI summarizes the available results of exploration in this area and the area covered by Bulletin XLIV.

In Part II, consisting of the detailed township maps, and the accompanying descriptions, each township is fully described under the following heads:

Surface Features.—Topography, profiles, glacial geology, roads, timber, and other resources.

General Geology.—Location and character of outcrops, petrologic descriptions, probable character of bed rock under the drift cover.

Magnetic Observations.

Land Classifications.

Exploration.

The township reports are arranged in order from south to north, beginning with the easternmost in the southern tier, and taking in succession those to the west. The succeeding tiers are taken in the same order from east to west. This is adopted as the most convenient order for reference, as the magnetic lines usually trend somewhat north of east, and the continuation of the lines in any township is more likely to be in the township east or west rather than in those north or south.

CHAPTER I

GENERAL INTRODUCTION

AUTHORIZATION

The Wisconsin legislature of 1913 passed an act directing the Geological Survey "to examine the lands of the northern part of the state and classify them in accordance with their mineral content and geological and other evidences of the presence of minerals" and appropriated funds for the carrying on of the work in the two succeeding fiscal years. A similar appropriation was made in 1915, when the townships covered by this report were examined.

PREVIOUS GEOLOGIC WORK

No detailed work and, in fact, very little reconnaissance work of a geological nature had been done in this area prior to 1915. On the north the Gogebic Iron Range had been discovered and surveyed during the decade preceding the Civil War. In 1877 F. H. King made a reconnaissance survey of the north and south forks of the Flambeau River, but as his report[1] shows, his attention was confined to the outcrops of granite and gneiss along the immediate vicinity of the streams. He contributed no data to the geology of the interstream area. Practically the entire expanse to which the present report is devoted was regarded as a "granitic and gneissic complex".

To the east of the northern part of the area concerned in this report (Fig. 1) magnetic work and drilling was done by the Carpenter group[2] in 1911, 1912, 1913, and 1914. Thirty-two townships were examined and drilling upon magnetic lines proved the presence of magnetic iron formation and schists.

During the field seasons of 1913 and 1914, 88 townships shown in Figure 1 were examined by this Survey and the results were

[1] Geol. of Wis., Vol. IV, pp. 582–621.
[2] R. C. Allen and L. P. Barrett, Michigan Geol. and Biol. Survey, Pub. 18, Geol. Series 15.

published.[1] In 1915 twenty townships were mapped and land classification advance sheets were issued in the spring of 1916.

LOCATION

The area covered in this report serves to complement the area embraced in Bulletin XLIV. It comprises parts of Price, Rusk, Sawyer, and Ashland counties. Its position in relation to the various productive iron districts is given on the general map, Figure 1. This shows the districts mapped by the U. S. Geological Survey, by the Michigan Geological Survey, and a large area along the northern boundary of Wisconsin recently surveyed by the Carpenter group mentioned above. It also shows the general area of pre-Cambrian rocks which is not covered by the younger horizontal sandstones of Cambrian age.

In order to show general relations, Plate I of Bulletin XLIV has been brought up to date and combined with the geological map of this area to make Plate I of this report.

REASONS FOR LACK OF EXPLORATION FOR IRON IN NORTHERN WISCONSIN

There are four good reasons why only a very moderate amount of exploration for iron has been done in northern Wisconsin.

1. The most important of these is the relatively great thickness of glacial drift and the consequent lack of rock exposures. With the exception of the Cuyuna range—the most recently developed—the productive iron ranges of the Lake Superior district center closely about localities where the ore was found outcropping by the early explorers, or by the government land surveyors, or where ore was exposed by overturned trees,—found "at the grass roots". In contrast to this, most of northern Wisconsin lies close to the great terminal moraine of the latest ice invasion where the glacial deposits cover the country deeply, and in but few places do the rocks appear at the surface. Thus little could be determined visually as to the kind of rocks present without expensive drilling, and test-pitting, through drift which oftentimes is more than one hundred feet thick.

2. Mining men for many years had comparatively little confidence in the value of magnetic attraction as a guide for explora-

[1] Wis. Geol. Survey, Bull. XLIV.

tion. This was undoubtedly due to the idea that strong magnetic attractions were the only important ones. Years of unsuccessful experience in prospecting strongly magnetic areas had resulted in prejudice against all magnetic attractions. It is only since the discovery of the Cuyuna range that the real significance of magnetic

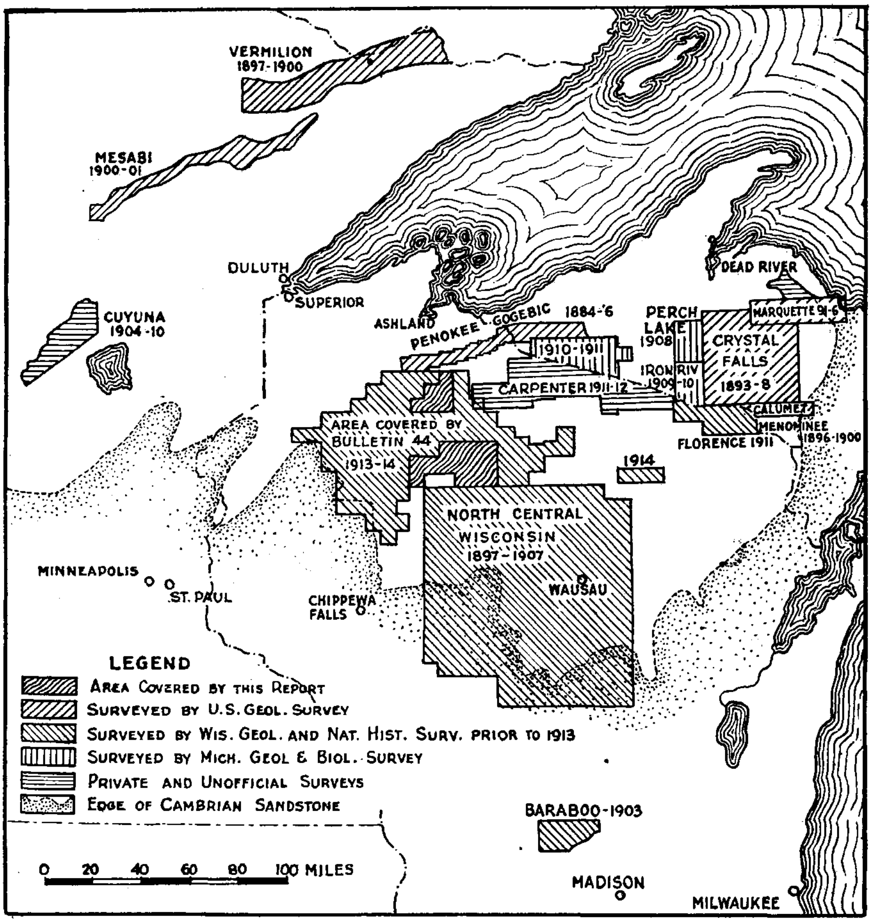

FIG. 1. Areas covered by geologic surveys of the Lake Superior Iron District.

data has been adequately appreciated. The very creditable work of Adams in developing this great range, with magnetic attraction as his only guide has decidedly altered the general opinion of the mining men. Magnetic methods of exploration at once won the respect of the mining profession, and attained a position as one of the most important means toward extending the iron-producing area of the Lake Superior region. The appreciation of the value of detailed surveys for the purpose of getting all the geologic and magnetic data that can be found is decidedly greater than it was twenty years ago and is bound to increase in the future. If these facts had been appreciated at the time the Gogebic range was opened, this whole pre-Cambrian area would have been examined most carefully.

3. Failure of this area to attract many explorers was due to the fact that in all the old ranges the ore was associated with quartzite, and the possibility of finding great iron ore deposits independent of quartzite was not appreciated. Since all the known quartzite areas in the Lake Superior region were explored to a greater or less extent before 1895, the areas in which no quartzite is to be found at the surface had never been of interest to the prospector. It remained for the development of the Cuyuna and Iron River districts to prove that iron formation need not be associated with the quartzites.

4. Of the few outcrops in northern Wisconsin nearly all were granite and other igneous rocks which were all supposed to be of an earlier geologic age than the iron-bearing formations. The reconnaissance maps of the early reports showed this as a great area of ancient igneous rocks in which there was no likelihood of the younger ore-bearing rocks being found. That these maps were based on a very small number of observations, and that no detailed surveys had ever been made here was not appreciated by the men interested in iron mining, and so the idea grew in their minds that it was a waste of money to search for iron south of the Gogebic Range.

Fortunately this belief has changed and recent discoveries of ore in outlying districts previously supposed to be barren, have convinced many that no large area should be condemned without a careful magnetic and geologic survey. The success of such surveys in leading to the discovery of several large deposits of ore in the last few years has engendered confidence, and capital is willing to follow up such surveys and to spend money in a search for ore in the favorable localities.

PURPOSE OF THIS WORK

In the light of this condition of affairs as outlined in the preceding paragraphs, it was apparent that it was of the greatest importance to get the facts, so far as they could be secured, if any intelligent search for iron ore in northern Wisconsin were to be made. It was known that northern Wisconsin is underlain by pre-Cambrian rocks. Along its whole northern and northeastern border this region is continuous with the pre-Cambrian rocks of northern Michigan in which the iron-bearing rocks are common. It seemed quite illogical, therefore, to accept the opinion of some of the mining men that the "ore stops when it gets to the Wisconsin line", because the principal geological difference between the areas is in the thickness of drift cover. For this reason while exposures of rock are comparatively numerous in the mining districts of Michigan, there are few in northern Wisconsin.

Therefore, the main object of the survey was *to discover the evidence that exists as to the presence or absence of iron-bearing rocks, and as to the geologic structure of the region.* There were two subsidiary objects to be served by the accomplishment of the main object. One was the prevention of waste of money and effort, to as large an extent as possible, by pointing out the most favorable places for exploration, and thus concentrating the attention of explorers upon places where they were most likely to be successful. A second object was to reduce the present practice, followed by most of the holders of large tracts of cut-over lands, of reserving the mineral rights when land is disposed of to settlers. It was known in a general way that northern Wisconsin had mineral possibilities, and so long as there was no classification of the land into "non-mineral" and "possibly mineral" the safest policy was to withhold all mineral rights. This worked a hardship upon the settlers as the mineral reservation acted as a cloud upon the title. A careful classification of the lands will discourage the holding of mineral reservations in areas where the possibility of the presence of mineral is nil and will aid settlers in securing unclouded titles. It will also indicate to the owners which lands offer a reasonable chance of reward for exploration and thus encourage the development of an iron mining industry, if one is possible.

It must be borne in mind that the conclusions of the geologist are but logical inferences based upon experience and study in his special field and are drawn from such facts of observation as are available. The geologist's report on a matter of this kind is of value insofar as he is thoroughly familiar with the occurrence of ore and is able to draw conclusions and see relations which are not apparent to the untrained man. If observable facts are few, a fair report must so state, in order that those who rely upon his advice may be able to judge of the reliability of his conclusions. If observable facts are so limited as to permit of no conclusions, this must be conscientiously brought out.

In this report it has been the purpose to give the facts as completely as possible, so that others can build upon them by closer work and more detailed observation, and to separate the facts carefully from the inferences based upon them. For this purpose a classification of lands has been adopted, as outlined in Chapter V, which gives at a glance the degree of certainty with which the conclusions were drawn. Owing to the scarcity of observable facts in many townships, much of the land is thrown into Class C, which includes all the lands where the evidence for more definite conclusion is lacking.

AREA COVERED AND COST OF WORK

The area covered by this report is 20 townships, or 720 square miles or 460,800 acres. The total length of the regular traverses made by the geologists employed on the work was 927 miles; 344 additional miles of traverse were made in following magnetic lines, making a total of 1271 miles.

The cost of doing the field work averaged 1.18 cents per acre. This low cost was made possible by very careful management and by working a large area of continuous townships. Work of a similar nature, but on a smaller scale and covering noncontiguous lands, had cost private land owners from 6 cents to 12 cents per acre.

ACKNOWLEDGMENTS

In making a survey of this character a large number of men were necessarily employed for the three and one-half months of the field season. Nearly all were University students seeking this opportunity to gain practical field experience. In much of this work it was necessary to accomplish the survey by pack trips from the main camp, the men being away from camp for several days at a time. The faithful, diligent service of these men, their enthusiasm in the face of difficulties, their interest in the work which led them cheerfully to put in long hours during the day wading swamps immersed to their waists, or hunting for outcrops in the rain, and then to spend long hours in the evening plotting their notes on the field maps, are deserving of special commendation.

Field work of this character is a strenuous combination of hard physical labor and mental activity; and when this is continued for twelve or fourteen hours per day, seven days a week, oftentimes for weeks at a stretch, until the field geologist's Sunday—a rainy day—gives a brief respite, it takes excellent qualities to measure up to the work. The names of the geologists employed are given on the maps of the townships they helped survey.

Many of the lumber and land companies and private citizens showed special courtesies to the field parties and furthered the work in a way deserving of special acknowledgment. Among these are the management of the Kneeland-McLurg Lumber Co., Phillips; the Hines Lumber Co., Winter and Park Falls; the Mellen Lumber Co., Mellen; Mr. B. J. Nutter, Phillips; Mr. John Owen, Prentice; and Dr. Chas. Fenelon, Phillips. Postmasters, bankers, railroad employes, merchants and settlers, all extended many courtesies and were willing to aid the parties by giving information and other favors. To all these grateful acknowledgment is made for their assistance.

For information regarding exploration which has made it possible to write Chapter VII the Survey is greatly indebted to the following: H. I. Pearl, O. W. Wheelwright, Mrs. F. C. Edson, W. G. Pearsall, of the Adbar Exploration Co., the Weyerhauser Co., and the Crosby Exploration Co.

Such information given to the Survey by exploration has greatly increased the knowledge of the geology of the state. Excellent work in drafting the township maps for the engraver was done by S. M. Willis, H. N. Eidemiller, F. L. Conover, and H. B. Doke.

Railway profiles were furnished by the engineering departments of the respective railroads, and highway profiles were supplied by the State Highway Commission. These gave much valuable data, and the courtesy of the engineers is much appreciated.

CHAPTER II

METHODS OF DOING FIELD WORK

GENERAL PLAN OF CONDUCTING WORK

WORK OF GEOLOGIST AND COMPASSMAN

The field work was done by men working in pairs—a geologist and a compassman. The geologist made the observations with the dip needle, recorded them and the dial compass observations and the notes on the geology, timber and soil. He sketched a map showing as well as possible the country for a quarter of a mile on each side of the line traversed, with lakes, streams, swamps, cleared lands, houses, well data, roads, railroads, rock outcrops and all features that go to make up a complete map. In the evening the geologist inked in his notes, made a general summary of his observations of the day and plotted his results on the outline township map. On days when it was too wet to work in the brush for fear of injuring the instruments the geologist either searched for outcrops and exposures of glacial drift in the area between his traverses, or along stream courses; ran hand level lines along the roads crossing the township, to obtain data for the profiles; or worked on his notes and maps.

The duties of the compassman consisted in making a pacing traverse, finding corners (assisted by the geologist as time permitted), and making observations with the dial compass. By means of the pacing traverse the geologist was enabled to locate the features he was mapping in relation to the last found government land corner. On rainy days he assisted the geologist in his search for outcrops and exposures of drift, in running the hand level lines and in drafting the field maps and reports.

LOCATIONS

The government land corners—section corners and quarter corners—were the basis of all locations. In some parts of the area the land survey was conscientiously done and most of the corners could be found, but in many townships the work was very poorly done and much difficulty was experienced in finding them. The corner stakes were never set in large parts of some townships, although the field notes are recorded in due form as though the work had been done. Lumbering operations and forest fires have also contributed to the difficulty of finding corners.

Due to the conditions described, and to the errors of the compassman in pacing, it is evident that locations must be somewhat wrong in many cases. If difficulty is met in relocating the magnetic attractions, outcrops, or other features shown on the maps, it will probably be of assistance if some nearby feature, such as a stream crossing, the edge of a marsh, or some other easily identified place is taken as a starting point. The work was checked, so far as it was feasible to do so, and it is believed that the locations given on the map will be found to be reasonably accurate.

ORGANIZATION OF FIELD WORK

Each party consisted of three geologists—a chief and two assistants—three compassmen, and a cook. Owing to the necessity for giving close supervision to the work and aiding in the correlation of the work of the different parties, a thoroughly experienced man was put in charge of a number of parties. Mr. E. F. Bean had charge of the parties in the field in 1915. He visited the different camps frequently, checking up the notes and maps, going out over the work to see that the geology was being properly interpreted, and keeping the parties up to a maximum of efficiency.

Each chief of party was responsible for the work of the men in his charge, assigning to them their traverses, and keeping the work balanced so as to have each geologist complete his share of the township at the same time as the others.

As a rule traverses were made north and south on the section and quarter lines. In some townships the traverses were made on the section lines only. If magnetic attractions were found, short traverses were sometimes made across the belt of attraction at closer spaced intervals.

SPECIFIC INSTRUCTIONS TO FIELD PARTIES

RELATIONS TO THE PUBLIC

Every employee of the Survey is expected to conduct himself with politeness and propriety in all his relations with the public.

When persons make inquiry concerning the nature of the work being done, courteous answers should be given. Giving out any specific information regarding the results arrived at in the course of the work is forbidden.

PRIMARY PURPOSE OF SURVEY

It should be constantly kept in mind that the primary purpose of this work is to classify the lands with regard to their mineral possibilities. The classification of each 40-acre tract seen in the day's run should be made in tentative fashion during the day or that same night. When the township map is made up the final classification should be put on every 40. A list of all 40's in classes A and B should accompany the township map and should state all evidence from geologic relations, magnetic readings, outcrops, glacial drift, and other sources, upon which the classification is based. In stating this evidence both facts and inferences should be given, with a most careful distinction drawn between the two, for it should be remembered that the evidence will be scrutinized very carefully by many persons, and while the geologist's inferences can be proved wrong without serious harm, his observations of fact must be complete and above criticism.

The classes into which the land will be divided are:

Class A.—Known to contain iron formation, shown by

1. Outcrops.
2. Tracing magnetic line from known outcrops.
3. Exploration records.
4. By contiguity or relation to known iron formation.

Class B—Probably containing iron formation, shown by

1. Abundant local angular iron formation drift with or without magnetic line.
2. Moderate local drift of iron formation with a good magnetic line.
3. Magnetic lines known to be associated with slates or other Huronian sediments.
4. Geological relationship showing a succession which elsewhere contains iron formation but shows no magnetic line or other evidence.

Class C1—Probably underlaid by Huronian rocks and crossed by magnetic lines having continuity and a fair degree of uniformity.

Class C2—Possibly underlaid by Huronian rocks but having either no magnetic lines, or very irregular magnetic lines, and no other indications of iron formation.

Class D—Containing no iron formation.

1. Includes areas of rocks not associated with iron formation, such as granites, etc.

NOTE BOOK

Map Page.—As a rule the center line of the right-hand map page should be used for the east line of the section, and the center line of the left-hand page for the center line of the same section. This permits all information pertaining to forties on either side of the traverse to be recorded on a single page.

Indicate by an arrow the direction of traverse, with the pacing distance between corners. Fill all blank spaces at the top and bottom of page.

Be sure to put on the field map everything desired for the final map, so that the draftsman can copy your map and have it correct without asking questions.

Notes on Geology.—Notes referring to the center line should be entered on the preceding ruled page. Notes on the east line should be recorded on the ruled page following. The best time to write up your observations is when you are making them. "The field geologist should always bear in mind the fact that he will probably never again see the particular locality he is studying, and should therefore aim to make his observations so thorough that he will never again need to see it." Use sketches freely in your notes.

Describe each corner found. In case a corner is not found, explain what conditions prevented the finding of the corner.

The work should be so arranged that the notes on a single township are in one set of notebooks, so that they, together with the township report, may be turned over to the chief of field parties, and a new set of notebooks used for the next township.

When the work is completed, index the notebooks, arranging the sections in numerical order. In case a geologist uses more than one notebook, each notebook should have an independent index showing only the sections contained in that notebook.

Reserve pages 96, 97, and 98, of each notebook for specimen index using the following form:

Office No.	Field No.	Description Page	Map Page	Kind of Rock	Office Classification

The first column should be one inch wide and left blank. In this index indicate by a star all specimens from which a slide should be made. In notes you should explain why a slide is desired.

TOPOGRAPHY

In this area the glacial symbols will be used to indicate the nature of the topography. Streams, swamps and lakes should be indicated by proper symbols. (See list of symbols and abbreviations.) Use solid lines to show streams, swamp boundaries, etc., as far each side of the traverse as you know their locations, and show their probable extensions for ¼ mile to the right and left by dotted lines. Be careful to show correctly on your map the width of the larger streams. Always indicate your estimate of the height of hills, depths of valleys, etc.

Observations on Topography.—Be on the alert for any evidence of pre-glacial topography, as this may have a bearing on structure. The course of a pre-glacial valley, especially if wide, was probably determined by less resistant formations, such as slate or iron formation. Present drainage may or may not follow pre-glacial drainage lines, but a valley, now occupied by lakes, streams and swamps or by one or more of these features, with the peneplain surface rising above it, may mean a pre-glacial valley. If such a valley has rock outcrops on one side and the strike coincides with the trend of the valley, you have some evidence as to the structure in the valley, even though no magnetic lines are found there. Again, if there are no outcrops in the upland, but a magnetic line is found which has the same general strike as the valley, you may feel quite certain that the valley is pre-glacial, and that the underlying rocks are non-resistant. If there is a magnetic line in the valley, you have evidence that possibly indicates iron formation. A broad lowland surrounded by higher land with resistant rocks outcropping, may be safely assumed to be underlain by non-resistant rocks, such as schist, slate, soft iron formation, etc. You should endeavor in every way to correlate magnetics, geology, glacial geology and topography.

The topography should be studied for evidence of the age and thickness of the drift. Well data should be secured wherever possible. *Data for wells which do not go to rock show that the drift is* *at least of a certain thickness.* If the drift is thin, the pre-glacial topography is slightly modified, while a thick sheet quite often obliterates the former topography.

The amount of post-glacial modification gives evidence of the age of the drift. If young, lakes and swamps are abundant, drainage channels are very shallow, and there is very little gullying on the hill slopes. In older drift lakes are fewer in number, and their shore features and swampy borders bear evidence of former greater extent. The depth of stream channels also is greater and drainage, is in general, better defined.

Hand Level Lines.—In spare time, such as compass correction days, or days not suitable for magnetic work, hand level lines should be run along the roads of the township, preferably so as to give an E–W and N–S profile across the township and connect with similar profiles in adjoining townships. In doing this it is convenient to use a ten-foot pole as a rod, on which the height of the instrument man's eye is taken as zero. *In all cases record the level notes in a notebook as follows: Station No., Backsight, Distance, Height Inst., Foresight, Distance, Elevation.* Be sure to make both foresights and backsights, and to make them as nearly the same length as possible. *Head level notes with a title stating where line begins, route and end.* Indicate in notes stream crossings, section corners, road corners, etc. Plot these on the scale 2 in. = 1 mile horizontal. 1 in. = 2 ft. vertical. Include in township reports a map showing routes followed in making profiles.

CULTURE

Show clearings, houses, roads, railroads, old explorations, test pits, etc. (See list of symbols and abbreviations.) Always get depth to water in wells, supply and character of water, depth to ledge, type of rock encountered, character of surface, etc. Inquire of owner for changes in water level. Much valuable information can often be secured from well drillers.

MAGNETIC OBSERVATIONS

In general a careful reading of the dip needle should be made at least every fifty paces. The horizontal deflection should be read at least every 100 paces. When a magnetic line is crossed, indicate in the notes your opinion as to the strike and dip of the formation, if you are able to form any from the readings. These deductions should be correlated with the structure whenever outcrops are present. The magnetic line should always be sketched in the field. This line should be crossed at frequent intervals so as to determine its location and characteristics in detail. Readings of the dip and dial should here be made at closer intervals. Record magnetic variations at the right or upper side of line of traverse, always indicating amount and direction of deflections at the right or upper side of line of traverse, always indicating amount and direction of deflections, as 4E, 8W. Ink these in your notebook with black. Dip readings should be recorded at the left or below the line of traverse. Ink these in your notebook with red.

On pages 92 and 93 of each notebook, in diary form, record the daily readings of the dip in camp, and the date of dip repair with new normal, together with dial readings on N–S line.

Date	Dip No.	Morning	Evening	Dial No.	Dial Reading
		Normal	Normal		
June 5	38	8°	7¼°	26	4E
June 6	38	8°	8°	26	4E
June 7	16	7°	7°	26	4E
June 8	16	7°	8°	7	4E

Manner of Holding Dip.—The geologist must hold the side engraved "W. & L. E. Gurley" to face the east and should himself always face the west when taking readings. Each man must be thoroughly familiar with Chapter IV.

Setting of Declination.—When the meridian has been established, determine the declination of each instrument and move the circle around until 0° coincides with true north, and fasten the circle securely.

Precautions to Secure Uniform Conditions.—Be sure that the compassman always stands in a constant position when reading the dial, and that his axe, knife, and knapsack are always carried in the same place. The geologist should take the same precautions with his load. Water bottles should be stripped of their metallic covers, if they have such, and a canvas cover substituted. These precautions are absolutely necessary.

Time.—Take the utmost care with watch time. Before starting in the morning all watches should be compared with the best time keeper, and set accordingly. The table of corrections should be changed from day to day to keep step with the equation of time. To avoid losing a valuable watch, each man should have his watch on a thong, rather than on a chain or fob. If water gets into a watch, put it in kerosene until it can be sent to a jeweler. All men must carry the watch for which jeweler's rating was furnished on May 1st.

GLACIAL GEOLOGY

General Directions

All exposures of glacial drift which are likely to be found along streams, roads, and railroad cuts, should be carefully examined for evidence of the character of the local bed rock. Slate fragments are seldom carried far, and angular fragments of dolomite, iron formation, or quartzite, are not usually found in abundance at a great distance from their source. Abundance of any kind of boulders is worthy of record. There should be at least one note recording the nature of the drift for every 40-acre tract.

1. *Direction of Glacial Movement.*—Observe striae, stoss and lee slopes, trend of drumlins and eskers, and transportation of erratics.

2. *Erosion Features.*—Observe glaciated surfaces—polishing, gouging, striation, plucking, etc.

3. *Pre-Glacial Topography.*—Note carefully any evidence, such as pre-glacial channels, as this may have a bearing on structure.

Glacial Deposits

1. *Ground Moraine.*—Indicate relief by the proper symbol, and by figures giving range in elevation in feet. Get all the evidence you can from wells, road and stream cuts, etc., as to character, thickness and age of drift, soil beds, vegetable or animal remains found below drift, etc.

2. *Terminal or Recessional Moraine.*—Show on your map the width and general trend of the terminal moraine belt. Be sure to indicate in your notes any facts which could be used in interpretation of the glacial geology.

3. *Outwash and Lake Deposits.*—Indicate extent. If there are abandoned stream channels, indicate their direction. If there are pits, describe them. The trend of bowlder trains and their relations to rock outcrops should be recorded.

4. *Drumlins, Eskers, Kames.*—Observe height, general direction and length. Note distribution relative to terminal moraines, to other drift features or to pre-glacial topography.

5. *Loess.*—Observe thickness, relations to glacial drift, topography and drainage lines.

Observations on Exposures of Glacial Drift

1. *Nature of Exposure.*—Railroad, stream or road cut. Depth of cut. New or old. In the latter case it is well to dig through the surface covering to determine the structure and materials.

2. *Composition of Drift.*
   (a) Materials—clay, bowlder clay, gravel, sand, loess, etc. Estimate percentages of the total volume made up by the bowlders, pebbles, and fine material, sand or clay.

3. *Structure of Drift.*
   Stratified:
      Outwash or terminal material.
      Thickness of strata.
      Direction and velocity of currents.
   Unstratified. Loose or compact.

4. *Weathering.*—Color of weathered and unweathered drift. If there is a weathered zone, examine the weathered pebbles, noting varieties of rock to see if the type of rock does not determine the amount of weathering, and thus give an older appearance to drift which is in reality no older than fresher appearing drift made up of more resistant rock. Note depth to which leaching is evident. Is the drift unconsolidated, well cemented or poorly cemented?

5. *Rock Represented in Bowlders and Pebbles.*—
   (a) Mechanical analysis of drift. One good method is to lay off an area two or three feet square, and pick pebbles under three inches in diameter from this. Care must be taken to make this count a truly representative one. If too large pebbles are selected, slate and other soft rock fragments will be overlooked. Pick 100 pebbles at random over this area and classify them, as: granite 87%, quartzite 11%, porphyry 2%. Such a count is valuable because it may show what the dominant local rock is. A number of counts taken in the same locality when studied in relation to known outcrops, may indicate the general direction of glacial movement.
   (b) Erratics. Care should be taken not only to note the common types of erratics, but also to note the occurrence of a distinctive type of rock which may be traced to a definite locality and thus give evidence regarding direc-

tion of ice movement. If the observer recognizes the rock, he should give its probable source; if probable source is not known, describe rock carefully or take sample.

6. *Difference in Age Indicated By*
   (a) Forest beds.
   (b) Remains of land animals.
   (c) Inorganic products formed during a time of ice recession, as bog ore.
   (d) Beds of lacustrine origin.
   (e) Beds of sub-aerial gravel, sand and silt.
   (f) Differential sub-aerial weathering.
   (g) Superposition of beds of till of different physical constitution.

PETROLOGY

General Directions

Exposures of Rock.—These are likely to be found along streams, road or railroad cuts. Odd time should be utilized in the search for these, such as the last few clear hours of a rainy day, or cloudy weather when working where it is necessary to have sun for dial compass readings. A rough pacing traverse should be made so as to give an approximately correct location for such features as are found. Every rock outcrop should be visited and inquiry should be made of the local people to see if they know of any that you have not seen.

Record location of outcrops with reference to a government corner. The description of the locations should be such that the outcrops may readily be found by anyone visiting the outcrop later.

The area and trend of the outcrop should be plotted accurately on the map. Be sure to sketch in the field all formation boundaries indicated by contacts, topography, or other evidence. If field determination of the rock is doubtful give best judgment as "probable". Give all possible hypotheses of structure. *Remember that in the field you are in a far better position to describe an outcrop adequately THAN YOU WILL BE AT ANY LATER TIME. Be sure to make the rock descriptions as complete as possible, so that even if the specimen is lost your identification may be used.* Make your petrologic descriptions quantitative rather than qualitative. When you say "coarse grained" you are comparing the size of grain with some standard in your mind, which no one else can know definitely. Instead of "coarse grained" use dimensions, as "crystals average ¼ inch in diameter." Endeavor in every way to make your observations definite in this way so that they convey clean cut ideas to one who has not seen the object described. This is the secret of good notes, and of good observation as well, for *to express an idea definitely you must first see it definitely.* The act of writing some obvious things will often suggest other less obvious ones.

Specimens.—Standard sized specimens about (4″ x 3″ x 1″) should be taken from each outcrop to show the various phases, such as weathered, unweathered, gradations, metamorphism, and such other features as should be shown.

Each geologist will carry a number of paper bags in which to wrap specimens. Put the specimen number on the bag with blue pencil in several places, so that identification may be certain. Put this number on the map and in the margin of the notes descriptive of the specimen. Ink these notebook numbers in black.

Igneous Rocks.—Origin and petrographic character. Structure and relations to other rocks, including jointing, schistosity and general metamorphism.

Sedimentary Rocks.—Petrographic character, constituent minerals; size, shape and color of grain; cement, gradations.

1. *Bedding.*—Ripple marks, cross-bedding, conglomerate, top and bottom of beds, etc. Note predominant direction of currents causing cross-bedding.

2. *Structure.*—Dip and strike of beds; pitch, length and direction of folds; relation of drag folds; faults, joints, cleavage-dip and strike, in zone of flow or fracture; secondary minerals, etc.

3. *Fossils.*—In case fossils are found, describe the horizon and bed in which they are found, collect a suite of specimens, wrap them very carefully and send to the office at once.

SOIL

"Many of the most important qualities of the soil depend on the relative amounts present of soil of different sized grains. This is called the *texture* of the soil. In order to classify soils it is therefore necessary to determine the relative proportion of the soil made up of each of the different sized grains. This separation of the soil is called *mechanical analysis* and in the system most commonly employed seven different sizes of grains are recognized and named as follows: fine gravel, coarse sand, medium sand, fine sand, very fine sand, silt, and clay. Practically all soils have at least a small amount of each of these different sizes. The following table gives the average texture of the most important classes of soils:[1]

AVERAGE TEXTURE OF IMPORTANT CLASSES OF SOILS[1]

	Mechanical analysis giving average percentage of soil separates in each class.						
	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Coarse sandy soil	5	15	25	30	10	10	5
Sandy loam soil	5	10	10	25	15	20	15
Fine sandy loam soil	1	4	5	20	25	30	15
Loam Soil	1	3	4	15	20	40	17
Silt loam soil	1	1	2	6	10	60	20
Clay loam soil	0	1	2	5	15	42	35
Clay soil	0	1	2	5	12	30	50

[1] Op. cit., p. 14.

Always mark the soil classification of every 40 the day the work is done. Preferably, this should be done at the end of every one-fourth mile.

TIMBER

There should be at least one note giving the kind of vegetation on each 40-acre tract, such as cultivated, hardwood, pine, slash, brule, sweet fern, etc.

[1] Soil Survey of North Part of North Central Wisconsin, Wis. Geol. and Nat. Hist. Sur., Bull. L, Soil Series 15, p. 13, 1916.

SYMBOLS

Exposures

drift
bowlders and talus
sediments without dip and strike
sediments with strike and dip
igneous rocks
gneiss and schist with dip and strike
dip and strike of secondary structures

Cultural and Economic

building
church
school
town hall
cheese factory
creamery
logging camp
cemetery
quarry
shaft
pit
opening in drift
well, non-flowing
flowing well in drift
flowing well in rock
exploration drill hole
roads
little used roads
trail
railroad
dump of excavated material
dam

Topography

gently undulating
roughly undulating
gentle slope showing direction
steep slope showing direction
cliff
gentle sags and knobs
pronounced sags and knobs
flat
flat with sags
wet land
spring
dunes

ABBREVIATIONS

Surficial Geology

A	Alluvial wash
B	bowlders
Cl	clay
D	drift
G	gravel
L	loess
M	marl
P	pebbles
Pt	peat, etc.
S	sand
T	till

Igneous Rocks, etc.

Br	breccia
Bt	basalt
Db	diabase
Dr	diorite
Ga	gabbro
Gn	gneiss
Gr	granite
Gs	greenstone
Po	porphyry
Ry	rhyolite
St	schist
Sy	syenite
Tr	trap

Characters

arg	argillaceous
brk	broken
cal	calcareous
crb	carbonaceous
crs	coarse
cty	cherty
fer	ferruginous
frg	fragments
fri	friable
hrd	hard
sft	soft
sid	sideritic
sil	siliceous
stk	sticky
wth	weathered

Sedimentary Rocks

ak	arkose
cg	congolmerate
ct	chert
dl	dolomite
gd	greensand
gw	graywacke
if	iron formation
ls	limestone
qt	quartz
qz	quartzite
rk	rock
sh	shale
sl	slate
ss	sandstone
tv	travertine

Soils

cl-l	clay loam
sdy-l	sandy loam
lt cl-l	light clay loam

Textures and Structures

amg	amygdaloidal
gns	gneissic
por	porphyritic
sch	schistose
str	stratified
tkb	thick bedded
tnb	thin bedded
xb	cross bedded
xln	crystalline
xln-c	coarsely crystalline
xln-f	finely crystalline

Colors

bf	buff
bk	black
br	brown
bu	blue
dk	dark
dr	drab
gn	green
gy	gray
lt	light
rd	red
wh	white
yl	yellow

In addition to the general instructions printed in each notebook, manuscript instructions in greater detail were given to each party as follows:

DIRECTIONS TO CHIEF OF PARTY

Much of the success of the party depends upon the ability, enthusiasm and leadership of the chief. In addition to planning and supervising the work of the party he will have the responsibility of selecting well-drained camp sites, seeing to it that sanitary conditions are maintained, that proper care of equipment is taken, that his men keep clean and as neat appearing as possible, that all men are courteous in their dealings with the public, and that the party is properly fed at moderate cost.

Notes.—Inspect the notebooks daily to see that the geologists are making the best possible notes and maps, and that these notes are kept inked in. If not satisfactory, have corrections made, then write your initials and the date at the bottom of each page of notes. See to it that the men are thoroughly familiar with the general instructions, symbols and abbreviations found in the first pages of the notebook.

Read carefully the instructions on magnetics and the general directions. See to it that all the men become thoroughly familiar with them. In addition to the daily discussion of field work you will find it very profitable to hold an occasional conference in which you quiz the men concerning these instructions.

PLANNING WORK

Plan the work from each camp so that each geologist has a block of sections. In this way he can be held responsible for the geology and physiography of his area. If the camp were located at the center of the township, one geologist might be assigned the eastern third, another the central third, and the other the western third of the township. Care should be taken so that the geologist who has a difficult area in one camp will be given an easier one in the next camp.

Except when working in a region known to have magnetic attractions, the work will be continued daily unless rain prevents. If the day is too cloudy to take dial readings, the traverse may be continued using the normal variation of the needle unless magnetic attraction is known to exist, in which case the traverse should be stopped, and completed when dial readings are possible. If necessary to stop the traverse because of cloudy or rainy weather, the time can be used to advantage in running hand level lines or in examination of drift exposures and outcrops.

WEEKLY REPORTS

On the paper township plats furnished make two weekly reports, each showing (a) magnetic lines and outcrops, (b) daily work of each member of the party, (c) mileage of each geologist for week, and (d) total mileage for season. Mail one report to the Survey office at Madison, and the other to your chief of field parties.

TOWNSHIP REPORTS

You are responsible for the report on each township which your party surveys. The preparation of this should be divided between yourself and assistants and written during the progress of the work while the facts are fresh in mind. Discuss fully with the member of your party all facts entering into the report. Free discussion of the facts observed will stimulate the interest of both your assistants and yourself and will lead to greater interest in the work and keener observation. Writing the report while you are still camped in the township permits checking up of doubtful or disputed points while you are right on the ground.

It should be borne in mind that failure to mention a subject in your report can only mean a failure in observation. You must carefully guard against the common failing of thinking that such treatment means that the subject is "the same as described in the last township." Failure to mention outcrops means only that you do not mention them. If there are no outcrops or exposures of glacial drift in the township omitting reference to them is not equivalent to stating their absence. *It is important to forcibly impress upon your own mind and upon your assistants' that positive statements are necessary.* When finished the report should be sent to your chief of field parties.

The township report should be an accurate, concise, but complete report based upon the following outline:

I. *Introduction*
  Time work was done, location of camp, personnel of party.

II. *Surface features*
  Topography
  Glacial Geology

  1. Ground moraine
    Topography
    Character of drift. Be sure to give relative proportions of the various materials and mechanical anaylsis.

2. Terminal Moraine
   - Trend and extent
   - Elevation above ground moraine or outwash
   - Topography
   - Nature of material
   - Mechanical analysis

3. Outwash
   - Extent and source
   - Topography
   - Mechanical analysis if material is sufficiently coarse

4. Thickness of drift, as shown by well data, cuts, etc.

5. Direction of glacial movement

III. Soil

IV. Timber

V. Roads and Settlements

VI. General Geology. If wells reach ledge be sure to determine what type of rock is found. Careful description, giving location and size of outcrops, structure and a good petrologic description of each.

VII. Magnetic Observations
Trend of lines and all deductions you are able to make regarding structure of underlying rocks and cause of attraction.

VIII. Land Classification
In this be careful to state the evidence upon which you base your classification

IX. Exploration
Describe any exploration that has been done. Find out who did the work, when, etc.

X. Economic Geology
Be sure to include road materials under this heading

XI. Miscellaneous
1. Map changes, etc.

TOWNSHIP MAPS

Accompanying the township report field maps made of the blank township plats furnished, must be submitted. Each traverse should be plotted upon the township plats as quickly as possible after it is completed. The purpose of this is (a) to enable you to plan your traverses more intelligently and (b) to enable you to finish the maps in a very short time after the completion of the survey. This work may be done evenings, on rainy days, or while compasses are being corrected. The four maps should show the features named below.

I. Map showing Geology and Magnetics. Study specimen map furnished you. (Scale 2 in. = 1 mile.)

1. Drainage and culture.
2. Magnetic readings and lines.
3. Geology—Rock outcrops, with dip and strike, formation boundaries, predominant varieties of rocks represented, bowlders of iron formation or ore, shafts, drill holes, pits, etc.
4. Explanatory statements as on sample map.
5. Classification of lands. Put this on in pencil only.

Note: In making this classification it is desirable to represent the gradation between classes which the geologist will have in mind, e. g. is a certain 40-acre tract B+ or A—. These should be recorded only in the notebook and the unmodified letters used on the township map.

II. Map of Surficial Geology. Study specimen map. (Scale 2 in. = 1 mile.)

1. Topography and culture. This map should give a good general idea of the surface of the township and the more important single topographic features by means of contours. The contour interval may be determined by the character of the country and the amount of hand level work that is done.
2. Glacial Geology. Sketch the outlines of terminal moraines, show extent of ground moraine, outwash, etc. Location and trend of drumlins and eskers, trend of striae, bowlder trains, etc.

III. Soil map. Study specimen map. (Scale 1¼ inch to mile.) Make a general subdivision of the township into soil areas.

IV. Timber map. Study specimen map. (Scale 1¼ inch to mile.) Make a general classification of the timber. Put a small x in center of all isolated cut-over 40's, and outline large cut-over areas. Indicate cleared 40's by a small circle in center of 40.

MISCELLANEOUS DIRECTIONS AND CAUTIONS

Blazing. When an original or re-established corner is found, blaze section lines 100 paces each way from the corner. Make a fresh blaze at corner and print W. G. S., date, and the proper description of the corner as,

Cor. $\frac{2 \mid 1}{11 \mid 12}$ T. 42 N., R. 14 E. or ¼ S. $\frac{1}{12}$ T. 42 N., R. 4 W.

When the original or re-established corner is not found, do not mark this as a corner but mark it as "1000 paces N. of E¼S, section 21," etc., so that others who find the blaze later will not be misled.

Photographs.—The Survey desires a moderate number of photographs in each town—say six to ten—showing both the *usual* features that are characteristic of the topography, timber, etc., and the more striking *unusual* features that exist. If you have a camera the Survey will pay for films and developing. Exposed films should be mailed to Madison for development. As many prints as desired may be had by the camera owner at the cost of prints. Take time exposures with small aperture wherever possible, as these give best results.

Forest Fires.—The greatest care must be taken to prevent forest fires. No matches should be dropped without seeing that all fire is out. If a fire is built for any purpose, be sure that it is extinguished when left. Cigarette smokers must make sure that butts are thoroughly extinguished before being thrown away.

Fire Arms.—These are not permitted in camp.

Tenure of Jobs.—No man can hold his job if he does not make good. If a man's work is not up to standard, warn him, aid him in every way you can and try to improve his work. Consult with your chief or field parties, so that he may be prepared to replace undesirables with new men.

Care of Equipment.—You will be held responsible for the equipment furnished you. Itemized lists of Survey property accompany each camp outfit. Check over these lists and report any shortage. You will be checked out at the close of the season.

Accidents.—As soon as you get in camp, secure from each member of your party the name and address of the person to be notified in case of accident. All precautions will of course be taken to avoid accidents, but your men should have in mind just what to do in case an accident occurs. In your camp chest is a small book, describing first aid to the injured. All men should be familiar with this. There is also a small emergency medical outfit. Be familiar with its contents and insist that it be kept for emergencies.

CHAPTER III

GENERAL GEOLOGY

INTRODUCTION

The rocks of the earth's crust are so largely concealed by soil, glacial drift or other unconsolidated material that in few regions of great extent is any large proportion of the surface occupied by rock exposures. In mapping the geology of a district it is almost always necessary to extend an inference drawn from a few square feet of rock exposure to cover many acres, or sometimes many square miles. All the evidence afforded by every feature of the surface—topography, drainage, soil and vegetation—and also whatever other evidence is available, such as magnetic attraction, must be used to supplement the information given by outcrops. Even after most painstaking search for the facts it must be recognized that probably most of them are beyond the possibility of discovery by means ordinarily at the command of the geologist. For the foregoing reasons it is obvious that the description of the geology of any large area will require modification as new facts are developed.

In the area discussed in this report there are over 450,000 acres or 20 townships. Rock outcrops were found in twelve of these townships. The area of exposed rocks is very small, however, aggregating not in excess of four acres. This constitutes 1/1,000 of 1 per cent of the area mapped. With the small amount of information available from rock exposures it was obviously impossible to map accurately the limits of the various rock formations present.

For the purpose of classifying the lands one of the most important criteria available is the local magnetic attraction, which is found widely distributed over the area surveyed. By carefully tracing this attraction and studying the observations in detail it is possible to outline those areas in which it is most likely that Huronian sedimentary rocks, including iron formations, are present. The mapping of these areas depends upon the general principle that magnetic sedimentary rocks in the area south of Lake Superior are known to occur plentifully only in the Huronian series, in more or less close association with iron formations, therefore the finding of magnetic attractions of a kind usually caused by sedimentary rocks justifies the mapping of such areas as possibly underlain by Huronian rocks.

Unfortunately, however, the details of the geology of most of the area must remain a sealed book. This is due to the thick covering of glacial drift which fortunately is of such a character as to add greatly to the value of the region. It makes an excellent farming country out of what otherwise might have been a rugged, barren region. The drift has levelled the inequalities of the surface and given it a soil which is almost certainly much better than the pre-glacial soil. It is an undoubted fact that rich soil is a more valuable resource in the long run than is an ore deposit, and if the choice were to be made it would be better to have a rich farming country developed in this area than to have a rich iron range. A rich soil will continue indefinitely to support a fairly dense population, while a mining district must sooner or later be exhausted and lose its value. So it is not to be an unmitigated misfortune that the thick drift cover possibly will prevent the discovery of much iron ore that might be found if the drift were absent. The most desirable situation for the future of this region will be to have both the soil and the mineral resources developed to the greatest possible extent.

GEOLOGIC FORMATIONS

The rock formations of the area shown in plate I, which includes the area covered by Bulletin XLIV as well as that covered by this report, are given in the following table, youngest first:

Cambrian.—White, yellow and light brown sandstone poorly cemented.

Keweenawan.—Possibly Barron quartzite, and sandstone, including at least two separate unconformable quartzite formations, trap rocks and probably both acid and basic intrusives.

Huronian.—Flambeau quartzite, chert and iron formation at Bruce, and slate and schist in several localities; quartzites, dolomite and slate found in drilling; granite and basic intrusives; iron formations and slates indicated in many places by magnetic data but not exposed.

Laurentian.—Granite and gneiss in large areas, forming the base upon which the Huronian was deposited. In this are rocks which may be of widely different ages, but it is impossible to determine relationships when outcrops are small and isolated. With the granite and gneiss are included rhyolite, porphyry, basic igneous rocks and schists.

In this area covered by this report no outcrops of Cambrian sandstone, Barron quartzite, Huronian iron formation or quartzite were found. Because of the few exposures, the geologic column is necessarily incomplete. This does not prove that no rocks of Huronian age are present. In a region of such heavy drift, and in which the streams have done so little erosion, it is to be expected that the less resistant formations will be concealed by drift and only located by drilling.

In the Lake Superior region, of which this area is a part, geologic formations older than the Keweenawan have in many cases been profoundly altered from the condition in which they were originally deposited. They were covered by thousands of feet of other rocks which have been eroded away. The deep burial and consequent pressure to which they have been subjected, the crumpling and folding, the intrusions of igneous rocks, and the action of water have changed their original character in varying degree. In some places they are so much altered that it is difficult to determine their original character. In others they are changed comparatively little.

These rocks include both igneous and sedimentary formations and comprise all the common and some uncommon types of rock. It may be stated that at least three quarters of the total thickness of sediment is shale or slate. The remainder is made up of dolomite, quartzite, and iron formation. The igneous rocks are of many varieties varying from acid to basic and from coarse crystalline varieties to the fine-grained surface flows and volcanic tuffs. In order to give an idea of what pre-Cambrian formations may be found in this area and their relative age the following table is given, showing the geologic columns of several of the producing iron ranges.

TABLE I.

System	Series	Group	Crystal Falls District	Florence District	Penokee-Gogebic District	Baraboo District
Algonkian System	Keweenawan Series	Upper			Absent	
Algonkian System	Keweenawan Series	Middle	Not identified	Granite and gneiss (Keweenawan?)	Gabbros, diabases, etc.	
Algonkian System	Keweenawan Series	Lower			Conglomerates —Unconformity—	
Algonkian System	Huronian Serses	Upper Huronian (Animikie group).	Greenstone intrusives and extrusives. Michigamme slate. with its Vulcan iron-bearing member	Quinnesec schist, greenstone intrusives and extrusives. Michigamme slate, including quartzites of doubtful age, and Vulcan iron-bearing member	Greenstone intrusives and extrusives. Tyler slate. Ironwood formation (iron-bearing) Palms formation	Quartzite (upper Huronian?)
Algonkian System	Huronian Serses	Middle Huronian	Unconformity? — Negaunee (?) formation (iron-bearing) Ajibik quartzite Hemlock formation (volcanic), with iron-bearing slate member near top	Not identified	Absent	—Unconformity Granite, intrusive into lower formations Freedom dolomite mainly dolomite including iron-bearing member in its lower horizon Seeley slate Baraboo quartzite
Algonkian System	Huronian Serses	Lower Huronian	Unconformity? — Randville dolomite Sturgeon quartzite	Not identified	—Unconformity— Bad river limestone (cherty limestone) Sunday quartzite	Absent
	Archean	Laurentian series (intrusive into Keewatin)	Unconformity — Granites and gneisses		—Unconformity — Granite and granitoid gneiss.	—Unconformity — Granites, rhyolites, tuffs, etc. (Laurentian?)
	Archean	Keewatin series			Greenstones and green schists.	

HURONIAN FORMATIONS

Since there are no outcrops of known Huronian sediments in this area, it is advisable at this point to summarize the evidence upon the basis of which large areas have been mapped as Huronian, with the qualification that "these areas include all areas where it is probable that Huronian sediments are present." In order to weigh this evidence, it is necessary to have a clear picture of (a) the character of the pre-glacial surface, (b) the manner in which the glacial materials were deposited, and (c) the erosion by streams since the glacial period.

The character of the surface before the glacial period can be compared roughly to that of the Marquette range at present. In this range there are long, narrow depressions occupied by the Huronian slates and iron formations. These depressions lie between ridges of more resistant Huronian quartzites and dolomites. To the north and south are higher areas of older rocks, granites, gneisses and schists, of a character somewhat more resistant than the average of the Huronian rocks. This brief outline of the topography of the rock surface will apply in a general way to all pre-Cambrian areas. The granites, gneisses, and hornblende schists are commonly found in rather large masses. They are invariably more resistant than the average of the Huronian rocks and so the areas underlain by them are higher than the areas underlain by Huronian rocks. The only exceptions to this general statement are the Huronian quartzite and some highly magnetic phases of the iron formation which are more resistant to erosion than granite and so are found in hills higher than the granite areas. But quartzite and resistant phases of the iron formation are not always present in the Huronian series in sufficient thickness to have a marked topographic effect.

The form of the rock surface in this area was the result of millions of years of erosion, during which the streams in the less resistant rocks, such as the Huronian slates and iron formations, were able to cut their valleys deeper than the streams flowing on granite and gneiss. As a consequence the main valleys were located in the Huronian slate areas and the valleys in the more resistant rocks were tributary to them. This relation of drainage to Huronian slate areas has persisted through the glacial period to the present time in regions where the drift is not too thick. The main streams of northern Michigan follow in a general way the old pre-glacial valleys in the Huronian slates.

From the foregoing statements it is evident that the general elevation of the surface of the Huronian slates and iron formations should properly be expected to be lower than the elevation of the areas of granite and gneiss. A general idea of the rock surface is given in the cross-section, figure 2.

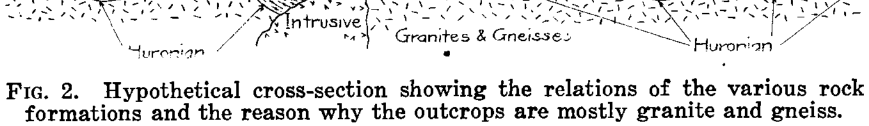

FIG. 2. Hypothetical cross-section showing the relations of the various rock formations and the reason why the outcrops are mostly granite and gneiss.

The second essential element of the general picture of conditions is the manner in which the glacial materials were deposited upon this rock surface. The general advance or retreat of the glaciers was by a series of oscillations or minor advances and retreats. During a general advance the minor advances predominated over the minor retreats. During a general retreat the reverse was the case. As the ice advanced its movement was retarded by elevations and relatively accelerated by depressions so that its edge was a series of small lobes in the valleys with re-entrants marking the divides. The constant melting produced streams which found their way down the existing valleys. The great amount of loose debris furnished by the glacier was more than the streams could carry so they gradually filled their valleys with it. After the glacier advanced over this valley fill and over the divides between the valleys, it melted back and left its load of bowlders and clay and sand in more or less irregular hummocks and sags. As it melted back the streams deposited more material in the valleys to be covered by the drift of the next advance of the ice and so on. Thus the deposits were built up, the thickest deposits largely as valley filling, and later, as the valleys were filled to the brim, as a general deposit over the whole country. At the position of greatest advance the minor advances and retreats probably continued in nearly even balance for a relatively long period before melting gained the ascendancy over advance and caused the general retreat. As a result of these processes the thickness of drift near the edge of the Wisconsin ice sheet is very great and very few ledges are left uncovered by drift.

The area shown on the map—plate I—is close to the edge of the Wisconsin ice sheet, so it differs from much of northern Michigan in having a somewhat deeper cover of drift and fewer rock outcrops. This second element in the general picture of conditions explains why practically all rocks, in both high and low areas are deeply covered with drift except in the extraordinary high quartzite hills.

The third essential element in the picture of conditions is the erosion accomplished by the streams since the glacial period. After the glaciers retreated the streams began to carve their valleys deeper. The drainage courses were frequently quite different from those preceding the glacial period. In many cases the streams were at right angles to the pre-glacial valleys. In cutting their valleys deeper some of the streams have cut into rock which formed the divides of the pre-glacial drainage. As may be seen best from figure 2, the first rock to be exposed was the granite and gneiss forming the more elevated portions of the rock surface. In this section the dashed line indicating the bottom of the main stream valleys is shown level with the tops of the granite and gneiss areas.

The third element in the general picture of conditions concludes the explanation of why, in an area where the only rock outcrops are granites, gneisses, and hornblende schists, it can be so confidently held that the presence of large areas of Huronian sediments is not only possible but a practical certainty. The old idea that Northern Wisconsin was a great area of granite and gneiss arose from the fact that these are practically the only rocks outcropping. The idea that the areas in which there are no outcrops may be underlain by Huronian rocks has not been given sufficient emphasis.

With this general picture in mind the other lines of evidence which go to prove that Huronian sediments are widely distributed in this area can be considered with profit.

As stated in the introductory part of this chapter magnetic observations are the chief basis for the mapping of these areas as Huronian. Without these magnetic observations it would be necessary to map the areas showing granite outcrops and include all the remainder as possibly containing Huronian sediments. With these observations it can be stated with practical certainty that the lands in Class C1 are underlain by Huronian rocks, but as exposures are lacking it is impossible to be absolutely certain.

There are three cogent arguments which thoroughly warrant the interpretation that certain of the magnetic attractions indicate the presence of Huronian sediments, and, more particularly, Huronian iron formations. These are first, the general close association of magnetic lines and Huronian iron formations in northern Michigan and in the Florence and Gogebic districts in Wisconsin—this whole region being continuous, and, so far as known, exhibiting general similarity of geologic conditions; second, the great abundance of iron formation pebbles and bowlders in the glacial drift, as shown by the drift analyses given on pages 43 to 44; and third, the discovery of iron formations and other Huronian sediments by drilling along similar magnetic lines in northern Vilas county, in the area covered by Bulletin XLIV (p. 280) and just across the state line in Michigan.*

These several lines of evidence justify the policy of mapping the areas containing Huronian sediments and iron formation. An inspection of the general map, plate I, will disclose the fact that in many cases areas of abnormal magnetic attraction are found in territory shown to be underlain by granites and gneisses, and by Keweenawan trap rocks. By studying the detailed observations shown on the township plats it will be seen that the magnetic attractions in these igneous areas exhibit characteristics decidedly different from those due to Huronian rocks.

From the information given by the outcrops to the west of this area and by the drilling in Vilas County, and in the area covered by Bulletin XLIV p. 280 the conclusion can be drawn that the Huronian rocks are largely slates, with iron formation, some quartzite and dolomite beds of minor importance, and some volcanic rocks. The indications of structure suggest rather close folding and steeply inclined beds. The strike is northeast—parallel to the general direction of the Huronian rocks in Minnesota and in the Gogebic range.

The steep dips, the soft schistose character of the outcrops in T. 35—8W., and the apparent lack of quartzite in most of the Huronian areas suggest that the character and structure of the formations and the manner of occurrence of the iron formation probably resemble most closely the conditions found in the Cuyuna range.

The relations to other formations are undoubtedly the same as in better known Huronian areas. Most of the granite, gneiss and schists are unconformably below the Huronian, but it is practically certain that some igneous rocks intrude the Huronian sediments.

IGNEOUS AND METAMORPHIC ROCKS

Rocks of these types are widely distributed over the area surveyed. The thick cover of glacial drift makes it impossible to discover their exact distribution, or to tell where sediments begin and these rocks leave off. While the areas shown as igneous and metamorphic rock on the map, Plate I, are believed to contain very little sedimentary rock, it is probable that the areas shown as

* Allen, R. C. and Barrett, L. P., Contributions to Pre-Cambrian Geology: Publication 18, Geological Series 15, Michigan Geol. and Bio. Survey, 1915.

Huronian contain a fairly large percentage of igneous and metamorphic rocks.

Exposures of these rocks are found in the twelve townships given in the following list:

36—5W	38—1E	41—4W
37—1E	38—1W	42—3W
37—2W	38—2W	42—4W
37—3W	41—3W	43—3W

The relation of the igneous and metamorphic rocks to the Huronian sediments is known only in a general way, chiefly from evidence found outside this area. The Keweenawan trap rocks occur both as intrusives and as surface flows overlying the Huronian. The granites and gneisses are in large part older than the Huronian, and form the base upon which it was deposited. Some of the granites are probably of later age and intrude both the Huronian sediments and the Keweenawan traps.

It is impossible to state which granites are of the older and which of the later age, with so little evidence as is presented.

The schists are almost certainly of more than one age. Some are probably metamorphosed Huronian slate sediments, others are mashed igneous rocks and possibly volcanic tuffs. The outcrops are too few to give reliable evidence and possibilities are the only statements that can be given. These outcrops are described in the separate township descriptions.

FACTS WHICH INDICATE THE PRESENCE OF AN IRON FORMATION

In this chapter and in chapter V general statements are given to prove that iron formation is present in this area. Each township description includes a discussion of the local observations indicating the presence or absence of iron formation in that township. In none of these places, however, is there a connected discussion of all the lines of evidence. Only those facts are mentioned which are found locally, or are needed to illustrate the point under discussion. For this reason there is given in the following paragraphs a discussion of the specific facts indicating the local occurrence of an iron formation which are obtainable from a careful geologic study.

Briefly stated, the lines of evidence found in this area are four:

1. The presence of definite Huronian sediments as shown by diamond drilling along magnetic lines in the territory between the northern and southern parts of the area covered by this report, chapter VI, 2, magnetic attractions, 3, abundant iron formation in the glacial drift, and 4, the evidence given by the topography. The last three are the ones that must be depended on in any particular small area. The general lines of evidence are given on pages 34 to 35.

For the purpose of this discussion it is necessary to recall what an iron formation is; that it occurs in beds that are continuous for considerable distances, like any other sediment; and that it may occur as a great formation 1000 feet or more in thickness, as minute stringers like the partings of shale in a sandstone, or as a formation of any intermediate thickness.

The term "iron formation" is used to denote a distinctive type of rock formation in which the iron ores of the Lake Superior region occur. This rock is a chemical sediment consisting of iron oxide or carbonate and cherty silica with varying amounts of ordinary sediment as impurities. These impurities are variously sand, clay, limestone or volcanic ash. With increase in the percentage of impurity the rock becomes a ferruginous quartzite (in which quartz sand is an important constituent), a ferruginous shale or slate (in which clay sediments are the abundant impurity), a ferruginous limestone, or a ferruginous volcanic ash. There is complete gradation from the pure iron carbonate or oxide and cherty silica combination of these other phases. Because of the fact that shales make up such a great part of all sediments the most common impurity in iron formation rocks is shale, and the most common gradation is to ferruginous shale or slate.

Not only is there complete gradation from iron formation to these common sediments named but there is just as perfect gradation from pure iron ores to iron formation. The pure hematite ore contains 70% of iron and 30% of oxygen, and pure magnetite contains 72% of iron and 28% of oxygen. The line of demarkation between iron ore and iron formation is not definite. It is determined by the demands of the market, competition with other ores, freight rates and other economic factors. Although lower grades are sold in small amounts in the Lake Superior region, the lower limit for ore is about 50% iron (natural). Material containing 40% to 50% of iron may be called ore on the assumption that sometime in the future this grade will be used. Rock containing less than 40% of iron is ordinarily called iron formation until its percentage of iron gets as low as 15% to 20%. The average iron content of 32,416 feet of drilling by the Oliver Mining Co.* in what was called iron formation by them was 36.8%. This is probably very close to the average iron content of the iron formations of the five principal ranges of the Lake Superior region in which this drilling was done. Quoting from Monograph LII, "These analyses include both the lean, and the partly concentrated parts of the iron-bearing formations, but do not include the available ore. If the partly concentrated parts of the formation are left out of consideration, the average would be 25 per cent of iron."

These iron formations have been metamorphosed in many ways so that they assume a number of different phases. They have been altered by solutions which have oxidized the iron and leached out the silica, thus producing the ores. They have been changed by igneous intrusion and dynamic metamorphism so that complex iron silicate and magnetite rocks have resulted, the amphibole-magnetite rocks or grünerite schists. This form is usually more resistant to erosion than other forms. They have also been altered to hard banded jaspers by folding and compression and the higher temperatures due to great depths of burial.

Various horizons of a single iron formation may be altered to these different phases, or adjacent parts of the same horizon may exhibit them, depending upon the conditions of metamorphism to which the different parts have been subjected, and the composition of the different parts before they were altered. It is quite common to find the basal part of an iron formation in the form of an amphibole-magnetite rock, and the upper portions either in the original condition or partly oxidized and leached. In such a case the basal part is more likely to outcrop than the remainder, and the wrong impression is quite likely to result, that the whole formation is the undesirable amphibole-magnetite rock.

If the whole of a thick formation has been changed to an amphibole-magnetite rock it is less likely to contain ore deposits than other phases of iron formation, but it exhibits strong magnetic attractions over its whole width. For this reason strong magnetic attractions have proved to be rather disappointing indications for the prospector. If the formation is thin and has all been altered

* Van Hise, C. R. and Leith, C. K., The Geology of the Lake Superior Region: U. S. G. S., Mon. 52, p. 491, 1911.

to amphibole-magnetite rock it will give strong magnetic attractions along a narrow belt. On the other hand, if only a limited horizon of a thick iron formation has been thus altered it will give the same effect as a thin formation entirely altered. The thick formation offers encouragement to prospecting and the other does not. Usually the only way to tell which case is present is to drill a number of holes and make a cross section of the formation. It is not uncommon to find a thin strongly magnetic formation paralleling a thick non-magnetic formation a few hundred feet distant.

If a thin iron formation or a thin horizon of a thick one is mildly altered by igneous intrusion or by dynamic metamorphism the result will be mild magnetic attraction along a narrow belt. These cases of mild attraction offer the greatest encouragement to the prospector in any area where magnetic attraction is one of the principal indications of the presence of iron formation. For this reason recommendations for exploration in the township descriptions are unfavorable or only mildly favorable where the magnetic attractions are strong. The most favorable magnetic indication is a long, continuous line of regular attractions varying not more than 10° or 12° from the normal dip needle reading. Many such lines are shown on the township maps of this area.

As stated in the following chapter, magnetic attraction *may* be caused by any kind of rock. The only igneous rock known to exhibit a long, narrow belt of attractions like that due to an iron formation is a greenstone or trap rock flow. Even in this case the attraction is very irregular when compared to that due to an iron formation. In the Lake Superior region there is probably not one case in fifty where a magnetic line, such as the one described above, is caused by any other rock than an iron formation. This iron formation may be thick or thin, rich or lean, but this can only be determined by drilling. The duty of the magnetic survey has been completed by suggesting that an iron formation is present.

Another indication of the presence of iron formation is the occurrence of iron formation and ore in the glacial drift. In order to obtain the percentage of different kinds of pebbles drift counts were made in many places. These are given on pages 43 to 44. The manner of making these counts is described on page 16. In some places the iron formation pebbles make a fifth of the total. In other places no iron formation is found in the drift.

Great abundance of iron formation in the drift is a strong indication that the ledge from which it came is close at hand. It becomes of great importance then to know the direction of movement of the ice and water which carried the material. The general movement of the ice sheet over the Huronian rocks of this area was from the northeast. Locally it changed its direction and moved northwest, west, southwest, or south. The drainage from the ice front for the most part found its way down the valley of the Chippewa and its tributaries. These local details should be worked out carefully before drilling is undertaken.

The character of the iron formation in the drift is not usually typical of the formation in the ledge. The hard jasper phases which are most resistant to stream action are certain to be the most common in the drift. The less resistant phases are more likely to be ground to powder and washed away, leaving only the lean hard parts.

There are two kinds of iron formation found in the drift in this area. Most of it is a massive red jasper made up of granules of chert and hematite, and is almost exactly like that found on the Gogebic Range. The other variety, found more commonly in the northern and eastern parts of the area, is banded red jasper and hard blue hematite.

The percentage of iron formation in the drift varies widely. In T. 42—4W, and T. 43—3W the drift counts show a high percentage of iron formation. This is due to the fact that outcrops of iron formation occur immediately to the north. As would be expected in the southern part of the area there is a high percentage of the more resistant and, therefore, topographically more important rocks, granites, rhyolites, and basic igneous rocks. The higher percentage of quartzite in T. 37—1W., T. 37—2W., T. 37—5W., in a region at a distance from known outcrops is suggestive, as is also the amount of sandstone in T. 36—5W. and T. 37—5W.

These observations are given to show the importance of the indications of the presence of iron formation to be found by a careful study of the glacial drift. When these are carefully studied in connection with the indications given by magnetic attractions much valuable information can be obtained.

A third indication of the presence of iron formation in any locality is given by the topography. As previously explained in this chapter, the Huronian series containing the iron formation are in relatively lower areas than the granite and gneiss. Topographic evidence of a pre-glacial valley, while of itself not giving any hint of the presence of iron formation, is nevertheless an important indication to be sought for in connection with the other indications described above.

The more general lines of evidence showing that iron formation rocks are present in this general area are discussed on pages 34 to 35.

TOPOGRAPHY AND DRAINAGE

The area described in this report is part of the Northern Highland of Wisconsin. It is a great plain produced by the erosion of the pre-Cambrian rocks, later covered by a thick cover of glacial drift. The general relief of the area is due to the elevation of this plain. The local relief is in large measure due to irregularities in the deposition of the drift. The maximum relief within a township is about 200 feet in 37—1E. The maximum relief as shown by hand level lines is as follows:

36—1E	55 feet	38—1W	80 feet
36—1W	170 feet	38—2W	45 feet
36—2W	125 feet	38—3W	125 feet
37—1E	184 feet	41—3W	60 feet
37—1W	70 feet	42—3W	120 feet
37—2W	75 feet	42—4W	140 feet
38—1E	35 feet	43—3W	120 feet

The lowest point in the area is 1180 feet on the Flambeau River at the south line of section 35, 36—5W.[1] The highest measured elevation is 1640 feet in the southeast of 37—1E. and S. W. of 43—3W. From the lowest to the highest measured point in this area is therefore 460 feet. As the level lines were run along roads, and the roads often follow stream valleys, it is likely that higher elevations than those shown on the profiles are numerous.

The topography varies from flat outwash plains, stream terraces, and lake plains through very gently undulating ground moraines to the abrupt hummocks, kettles and ridges of the terminal moraines. The details of topography are described in the township reports.

The thickness of the drift where known is given in the township reports and estimated where not known. In general it is true that the drift is thickest in T. 36—1E., T. 36—1W., and T. 36—2W., probably averaging 150 feet in thickness since this is near the southern limit of the Wisconsin ice sheet. The average thickness

[1] Profile Surveys of Rivers in Wisconsin: U. S. G. S., Water Supply Paper 417, Plate 12.

of drift probably becomes less as the northern limits of the area are reached, where 50–100 feet is probably the average thickness.

Since all this area is within the Wisconsin ice sheet, drainage is not yet established. Swamps of all sizes are numerous and there are many lakes. The streams have not adjusted their channels to the changes brought about by glacial deposition. As a result, rapids and waterfalls due to outcrops or to accumulation of bowlders, are succeeded by long reaches where the stream flows slowly between low banks.

All the drainage of this area, except the northeastern part of T. 43—3W. which is in the Lake Superior drainage area, flows into the Mississippi River. The Chippewa with its tributaries, Torch, Moose, Thornapple, Flambeau, and Jump, receive the drainage of the area.

The streams and lakes are a resource of the area that is not fully appreciated by those who are not familiar with this region. Hunters and fishermen now come here in great numbers. As its advantages come to be better known, and more good roads are developed, the number of tourists will greatly increase. Another resource that is but little utilized is the water power.

ANALYSIS OF GLACIAL DRIFT

The constitution of the glacial drift is one of the important criteria that must be used in this district to determine the character of the bed rock. Examples of the use of these drift analyses are given on page 34. The method of making them is described on page 16. A large number of such analyses were made in the field work in this area. The results are given in the following pages for the convenience of those who may wish to use them as a basis for the more detailed study of the constituents of the glacial drift that should be made before drilling operations are begun.

It is certain that the personal equation plays a large part in the selection of the pebbles to be counted. Even though he may be consciously striving not to select an unduly large proportion of any one kind of rock, a man can hardly avoid paying more attention than he should to the varieties of rock most interesting to him. In this work every possible indication of iron formation was diligently searched for, and it is quite probable that the geologists were influenced more or less by this fact. The initials of the geologist making the drift count (the name can be found on the map of the township) are given on each case so that the counts made by one man can be compared with those made by others.

The towns are arranged in the same order as the maps in Part II; the southernmost township is given first, then those of the next tier north beginning at the easternmost range and going west, then the next tier beginning at the east, and so on.

TABLE II.

Loca ion	Granite	Porphyry	Gabbro	Fine Greenstones	Schists	Quartzites	Sandstones	Iron Formation	Quartz	Other Rocks	Geologist
					T. 36 N. R. 1 E.						
S. E. ¼ 23	49	10	1	17	2	7	------	2	12	------	R. N. H.
N. E. cor. 4	59	13	2	13	2	------	1	2	7	1	R. N. H.
E. ¼ 29	54	------	------	23	------	3	7	9	4	------	M. K. D.
S. W. ¼ 11	48	10	------	26	------	12	------	4	------	------	G. M. S.
S. E. ¼ 27	64	------	2	12	6	4	4	6	------	2	G. M. S.
S. E. ¼ S. E. ¼ 20	51	6	2	23	4	6	6	2	4	2	G. M. S.
					T. 36 N., R. 1 W.						
N. ¼ 30	66	------	17	17	------	------	------	------	------	------	M. K. D.
N. E. ¼ 3	43	6	14	23	6	4	4	10	------	------	G. M. S.
W. ¼ 1	50	6	7	21	2	4	4	6	------	------	G. M. S.
N. ¼ 5	38	------	12	26	2	2	6	8	6	------	G. M. S.
					T. 36 N., R. 1 W.						
S. W. ¼ 26	59	3	6	8	3	3	6	12	------	------	M. K. D.
					T. 36 N., R. 5 W.						
Sec. 17	36	15	3	17	1	12	11	2	2	1	R. N. H.
S. W. ¼ 4	66	8	8	8	------	8	------	------	------	2	E. P. R.
					T. 37 N., R. 1 E.						
S. W. ¼ 36	36	15	------	33	------	------	2	9	------	5	R. N. H.
S. W. S. E. ¼ 19	68	2	------	18	------	4	------	2	------	6	G. M. S.
					T. 37 N., R. 1 W.						
E. ¼ 35?	31	2	14	11	1	13	4	7	13	4	E. A. K.
					T 37 N, R 2 W						
N. E. ¼ 6	12	2	19	30	3	19	4	5	4	2	R. W. B.
N. E. ¼ 9	4	8	29	34	3	5	8	4	5	------	R. W. B.

TABLE II.—Continued

Location	Granite	Porphyry	Gabbro	Fine Greenstones	Schists	Quartzites	Sandstones	Iron Formation	Quartz	Other Rocks	Geologist
T. 37 N., R. 5 W.											
S. W. ¼ 33	29	12	------	25	------	14	16	2	2	------	R. N. H.
N. E. cor. 7	34	15	2	21	------	6	15	7	------	------	C. W. H.
E. ¼ cor. 9	30	11	4	37	5	5	3	5	------	------	C. W. H.
S. ¼ 27	21	14	4	20	3	17	7	8	2	4	C. W. H.
T. 38 N., R. 1 E											
S. E. cor. 25	60	10	2	14	------	4	------	4	6	------	R. N. H.
T. 41 N., R. 3 W.											
Sec. 23	74	------	6	10	------	------	3	6	1	------	M. K. D.
S. E. ¼ 12	62	------	5	19	3	------	6	5	------	------	M. K. D.
W. ¼ 31	40	6	4	20	4	4	4	12	6	------	G. M. S.
T. 41 N., R. 5 W.											
Sec. 30	58	11	------	11	------	4	7	7	2	------	R. N. H.
N. W. ¼ 4	43	7	4	16	2	11	2	4	11	------	G. M. S.
T. 42 N., R. 3 W.											
N. W. ¼ S. W. ¼ 19	56	10	8	20	------	4	------	2	------	------	C. W. H.
N. W. ¼ 2	34	3	16	8	------	13	17	8	------	1	D. G. T.
T. 42 N., R. 4 W.											
N. W. ¼ 2	34	2	6	22	------	12	------	22	2	------	D. G. T.
N. W. ¼ 3	28	4	15	10	1	20	2	16	2	2	R. W. B.
S. E. ¼ 20	22	7	23	6	1	11	6	16	5	3	R. W. B.
N. E. ¼ S. E. ¼ 7	44	9	7	22	------	5	5	6	2	------	C. W. H.
T. 43 N., R. 3 W.											
S. E. cor. 31	43	------	2	27	1	6	4	12	5	------	W. L. D.
E. ¼ cor. 12	15	------	3	15	------	11	43	10	3	------	W. L. D.
S. W. ¼—S. W. ¼ 33	27	5	29	17	2	5	4	8	2	1	R. W. B.
T. 44 N., R. 2 W.											
N. W. ¼—N. E. ¼ 11	6	27	5	20	------	1	29	12	------	------	M. C. L.
Center 2	2	17	2	16	------	------	34	29	------	------	M. C. L
S. W. ¼—S. W. ¼ 8	7	16	3	21	------	6	44	3	------	------	W. F.
Near Center 17	6	11	6	23	1	3	44	5	1	------	W. F.

CHAPTER IV

MAGNETIC OBSERVATIONS

GENERAL PRINCIPLES

LOCAL MAGNETIC ATTRACTIONS

Magnetic observations are of value in geological work for the principal reason that they indicate the location and strike of bedded magnetic rocks. In many cases the approximate dip and the depth of burial of the formation can also be deduced from a series of observations. The magnetic attraction of rocks is due to the presence of magnetite. While the oxidation of pyrite frequently results in a product which is magnetic, and oxidized pyrite can oftentimes be followed by the magnetic attraction, this is usually a minor phenomenon, of veins and not of bedded rocks. Any rock in which magnetite exists in appreciable amount will show more or less magnetic attraction. This mineral is found in a great variety of rocks. It occurs in minor quantities in all igneous rocks and in very considerable quantities in some of the more basic varieties. It is also found in sedimentary rocks, either as a primary mineral, or as a secondary mineral developed in place, and in either case may form either a minute part or the major part of the rock.

Economically the most important rocks that contain magnetite, and therefore exhibit magnetic attraction, are the rocks known as iron-bearing formations. It is in the finding and tracing out of rocks of this character that magnetic observations find their chief value in economic geology. Magnetic observations are also very useful in tracing out the strike of other rocks, as greenstones, slates or quartzite, in which there are beds containing sufficient magnetite to exhibit local attraction, and in this way they give data on the geologic structure in regions where outcrops are few or lacking.

BRIEF GENERAL DISCUSSION OF MAGNETIC FIELDS*

The earth may be considered as a magnet in which the lines of force have the direction and vertical angles shown in figures 3 and 4. These lines of force show the direction which would be

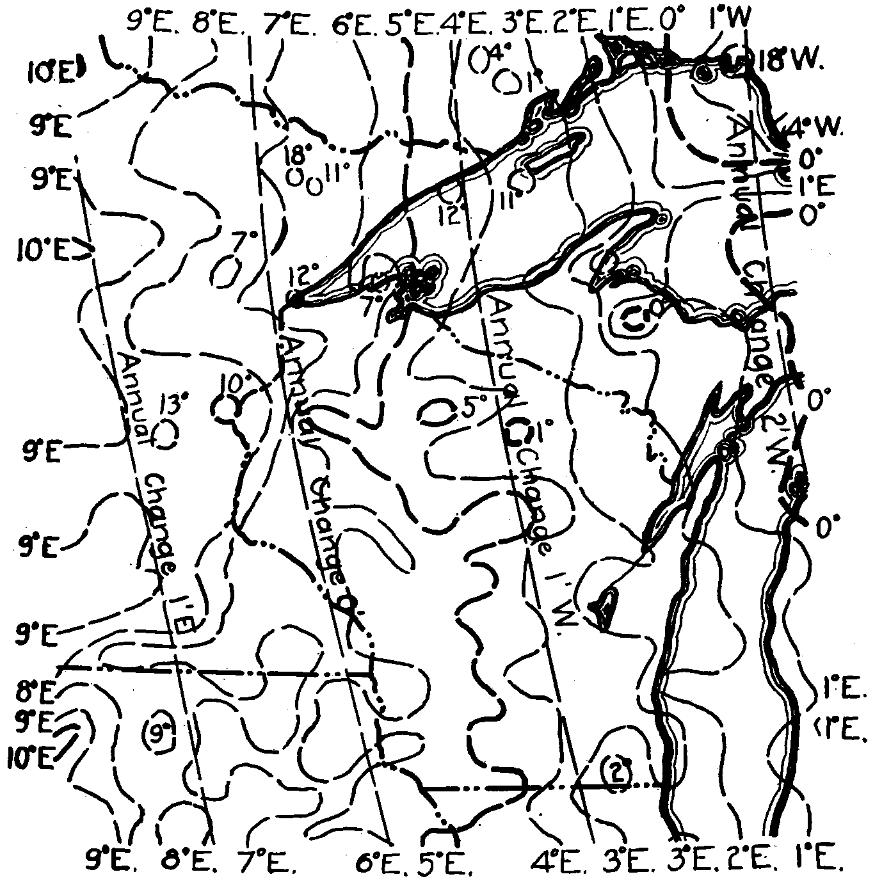

FIG. 3. Lines of equal declination and equal annual change. From U. S. Coast and Geodetic Survey chart.

assumed by a perfectly balanced magnetic needle free to swing in all directions. The variation (from true north) of the horizontal projection of the lines of force is known as the *declination*. The

* An excellent discussion is contained in "Principal Facts of the Earth's Magnetism and Methods of Determining the True Meridian and the Magnetic Declination," published by the U. S. Coast and Geodetic Survey, 1909. A very good general treatment of magnetism is "Magnetism and Electricity for Students" by H. E. Hadley, published by MacMillan & Co.

angle between their direction and the horizontal is known as the *inclination.*

In addition to this property of *direction,* the magnetic field possesses the property of *intensity.* If a compass laid upon a table is approached from one side by a bar magnet, the deflection noticed

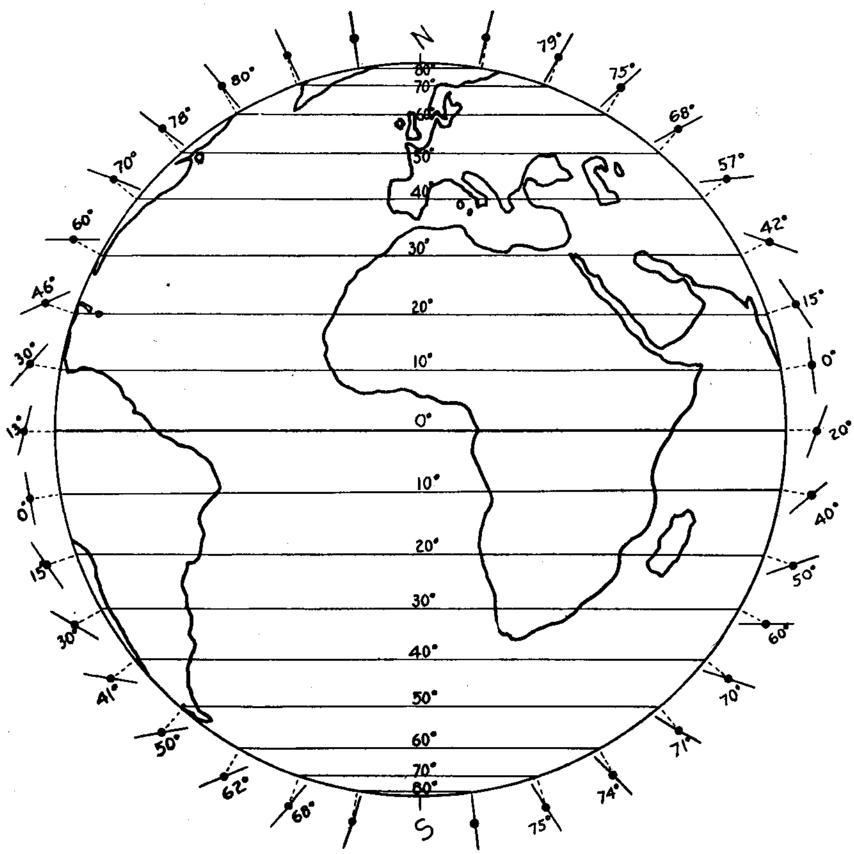

FIG. 4. Inclination of the magnetic field to the earth's surface on a great circle through the Lake Superior iron district.

will be greater as the magnet gets closer. The intensity of the field varies inversely as the square of the distance for a bar magnet and as the first power of the distance for a sheet magnet such as a magnetic iron formation. The field of attraction of a magnet is usually indicated in a drawing by lines of force, in which the spacing of the lines roughly indicates the intensity. If into such a field some magnetic material, such as metallic iron or magnetite is introduced, there is produced a local change both in the direction and intensity of the magnetic attraction.

Over any small area, such as a township, free from magnetic rocks, the direction and strength of the magnetic field of the earth are the same at one point as at another. The earth's normal field is for this reason known as a *uniform field* and represented by evenly-spaced parallel lines, as in figure 6. If into such a uniform field the geological processes of deposition, folding, metamorphism and erosion have introduced a magnetic formation, the effect on the field is of the same nature as that shown in the field of an ordinary magnet when a piece of iron is introduced. It is these local changes of the normal magnetic field of the earth, both in direction and intensity, which enable us to discover, by means of magnetic observations, the presence of covered rocks containing magnetite.

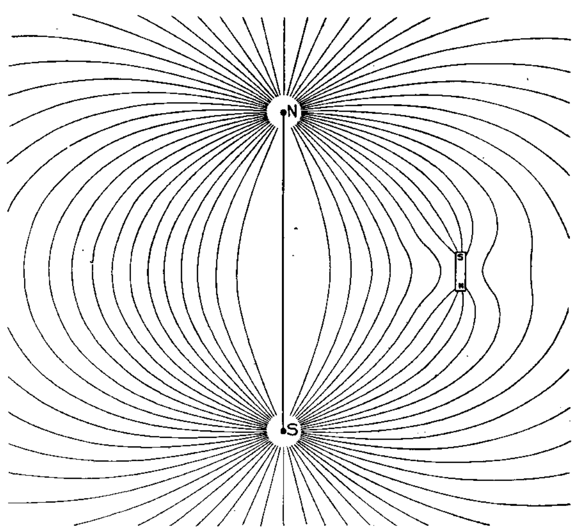

FIG. 5. The effect of a magnetic substance on the field of a larger magnet.

The magnetic field where local attraction is present may be considered as a combination of a uniform field (the normal field of the earth in that locality) and a non-uniform field due to the magnetic formation causing the local attraction. Figure 6 illustrates such a field—the parallel, equally-spaced, straight lines representing the uniform field of the earth, the dashed lines representing the field of the magnetic formation, and the heavy curved lines representing the resultant field. The figure is a section parallel to the magnetic meridian and the magnetic formation is assumed to strike east and west, and dip to the south.

If a horizontal line *S-S* be drawn anywhere above the top of the magnetic formation it would represent the surface of the ground, and the distance from it to the formation would represent the depth of the glacial drift. The directions of the lines of force affecting the compass needles would be given at the intersections of the line *S-S* and the heavy lines of the resultant field. It is readily seen that the angles at which *S-S* cuts the lines of the resultant field will vary as it is higher or lower on the drawing, and that the intensity of the field will decrease with distance.

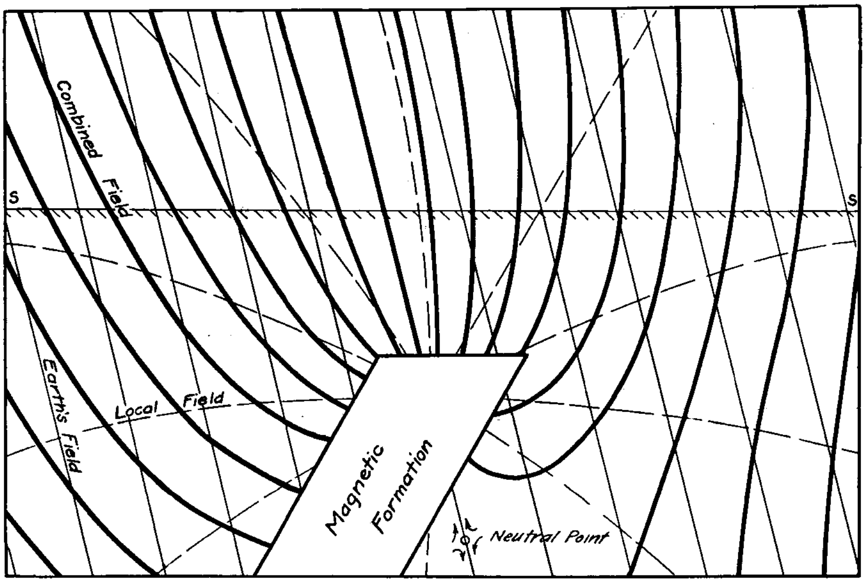

FIG. 6. A magnetic field due to the combination of the local field of a magnetic formation and the earth's field.

It is apparent that changing the strike of the magnetic formation from E-W, as shown in the figure, to N-S would make its field quite different. All the lines of force of the local field would lie in a plane perpendicular to that of the drawing. Intermediate strikes would have intermediate effects. Changes in the strength of the magnetic formation would also notably alter the configuration of the field. While all these changes and their effects on the local field can be worked out, either graphically or by computation, it is evidently too complex a problem to present here. Every person engaged in making magnetic observations should, however, picture to his mind the various cases and the effects on the resultant local field if he is to understand and interpret his results correctly.

Another point to note in figure 6 is the fact that there is a point where the field of the magnetic formation is equal and opposite to the earth's field—the *neutral point.* There would be another neutral point at the opposite pole if it were shown. At such a point there is no effective magnetic attraction. Consequently the horizontal compass needle will stand in any position, and the counterweight of the ordinary dip needle will hold it vertical with its north pole upward. Such neutral points are seldom found in field work, but occasionally one can be located when a strongly magnetic formation is found at the surface.

In the area covered by this report the normal declination varies from 6° to 3° east of north and the inclination is about 75° from the horizontal. Determinations made by the U. S. Coast and Geodetic Survey in 1912 give the following:

Place	Eastward Declination	Inclination of Earth's Field from the Horizontal	Horizontal Intensity in Gausses
Ladysmith	4° 20.8′	75° 02.4′	.16092
Birchwood	5° 44.4′	75° 27.1′	.15592
Park Falls	3° 58.0′	75° 27.9′	.15646

Magnetic attraction, like any other force, can be studied as the equivalent of any number of forces producing the same result. It is frequently most simple to consider this force as resolved into horizontal and vertical components, as H_R and V shown in figure 19, page 80. Either component may again be divided into local and normal components, as H_L and H_N.

A METHOD OF USING COMPONENTS

By dividing a field into its components it is possible to make a vertical magnetic triangulation to locate the attracting formation and find the depth of glacial drift covering it. The attraction at any point can be considered as being made up of two components; (1) the normal field of the earth, and (2) the local attraction, as described on page 79. If the normal direction and magnitude of the earth's field be determined at some distance from the local attraction, as described on pages 96 to 102, and several determinations of the abnormal attractions across the magnetic formation be made in the same manner, the facts can be plotted as shown in figure 7. In this figure the lines HR give the magnitudes and directions of the attractions at the points observed, HN is the normal magnitude and direction of the earth's field. Each force, HR, can then be considered as the resultant of two forces, the normal field of the earth, HN, and the local attraction, HL, due to the magnetic formation. After measuring HR and HN the triangle can be closed by the line HL, which gives the magnitude and direc-

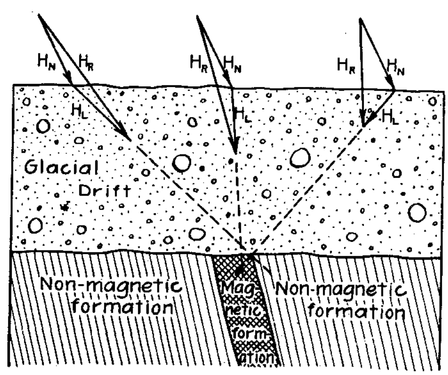

FIG. 7. Finding the depth and position of a magnetic formation.

tion of the local attraction. By extending these last, as shown by the dotted lines, their intersections will locate the cause of the local attraction within a very few feet, both in horizontal position and in depth. As the center of attraction is not at the surface of the formation, but is located a few feet below, this fact will tend to give a somewhat excessive depth. On the other hand, the slight curvature of the local field due to the small effect of the opposite pole will tend to give too little depth, so the two will balance each other more or less completely. The use of this method will make it possible to determine with a single drill hole the kind of formation causing the local attraction—a bit of information that frequently has taken two or three drill holes to discover. This method is most accurate when the drift cover is thick in comparison to the magnetic formation. If the formation is thick and the drift cover thin this method is an unnecessary refinement, as the ordinary instruments can be depended on to show the boundaries of the formation closely enough so that the formation can be penetrated by the first hole.

VARIATIONS IN THE MAGNETIC FIELD OF THE EARTH

These are of two orders, those that take place in regular cycles, and those due to magnetic storms. The cyclic variations are of several kinds; the minor variations due to the position of the moon with reference to the earth and sun, which are so minute as to be noted only with the most refined instruments; the daily variations, possibly due to the alternate heating and cooling caused by day and night; the annual variations; and the secular variations.

The *daily variations* in declination at points in the latitude of the Lake Superior region range from 6 to 9 minutes as a yearly average. These are by far the most important of all the variations from the point of view of magnetic exploration. The yearly average for Madison,* Wis., is given in minutes of arc as follows:

	A.M.												P.M.											
Hour	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Variation	0.1	0.0	0.2	0.5	1.0	1.4	2.6	3.2	3.0	1.7	0.7	2.5	3.5	3.5	2.6	1.6	0.7	0.2	0.2	0.2	0.6	0.7	0.2	0.1
	East										West								East					

It will be noted that the maximum eastward declination occurs at about 8 A. M. and that the maximum westward declination at about 1:30 P. M.

Through the kindness of Mr. R. F. Stupart, Director of the Meteorological Service of Canada and the Toronto Magnetic Observatory, who furnished manuscript copy of the observations, it is possible to present the following table showing the maximum and minimum daily variations for each month for the four years 1911-14. It is fortunate that the magnetic observatory at Toronto is at about the same magnetic latitude as the Lake Superior iron country, so the observations probably give a very close approximation to the variations affecting magnetic field work.

* Principal Facts of the Earth's Magnetism, p. 50.

Month	1911				1912				1913				1914			
	I.	II.	III.	IV.	I.	II.	III.	IV.	I.	II.	III.	IV.	I.	II.	III.	IV.
January	39.2	5	16	4	27	2.7	2	0	30.3	5.1	4	1	24	2.5	3	0
February	58	5.6	16	4	19.9	4	3	0	32.5	3.1	3	1	17.4	2.2	3	0
March	57.5	5.3	16	7	29.7	5.6	3	0	26.2	5.3	9	0	30.2	3.7	5	1
April	72.4	5.2	14	4	29.3	6.8	12	0	35.9	8.1	5	0	52.2	6.9	11	2
May	50.3	8.1	18	4	54.9	8.3	7	2	50	9	13	3	58.9	7	7	1
June	51.0	10.1	15	2	37	7.9	9	1	39	10.3	10	1	37.7	7.7	9	0
July	37.8	8.8	21	3	27.2	7.6	8	0	24.2	8	7	0	51.1	8.8	15	2
August	63.4	8.3	20	2	47	10.6	16	2	21	9.9	12	0	36.8	9.7	24	2
September	47.3	6.9	16	3	37.9	7.8	5	1	46.9	7.8	15	1	39.5	6.9	20	2
October	53	6.3	9	2	38.6	5.5	4	1	36.1	6.8	9	3	61.5	5.2	12	1
November	30.3	5	5	1	37.2	4.5	3	1	24.4	4.4	2	0	24.4	6.7	9	0
December	52.5	2	6	2	25.4	3.9	4	0	24.1	3.9	2	0	21	5.1	3	0

Columns numbered I show the greatest daily variation in minutes of arc for each month. Those numbered II give the smallest daily variation in minutes of arc for each month. Those numbered III give the number of days in each month in which the variation was more than 15 minutes of arc, and those numbered IV give the number of days in which it was more than 30 minutes.

The total number of days in the four years in which the variation exceeded 15 minutes is 450; of 30 minute days, 68. These totals are divided by months as follows:

Month	15 m. days	30 m. days	Month	15 m. days	30 m. days
January	25	5	July	51	5
February	25	5	August	62	6
March	33	8	September	56	7
April	42	7	October	34	7
May	45	10	November	19	2
June	43	4	December	15	2

The *horizontal intensity* varies on ordinary days not more than ¼ of 1%. In extreme conditions it seldom varies as much as 1%. The *vertical intensity* varies about 1-10 of 1% on ordinary days and about ½ of 1% on extreme days.

The *annual* variation of the declination is very small, amounting to a total of about 11 minutes of arc at Toronto.

The *secular* change is quite important. The declination at Boston varied from slightly less than 7° west of north, in 1790, to about 12½° west of north in 1900. The inclination varied from 68½°, in 1722, to 74½° in 1860, and in 1900 it was 73½°. The secular change of the declination in Wisconsin is very slight, being about 2 minutes of arc per year at present. This is due to the fact that this state is near the line of zero declination. In Rhode Island it amounts to 6.9 minutes, and in Oregon and Washington to 5½ minutes per year.

The annual and secular changes are not of such magnitude as to interfere in any way with magnetic exploration.

Magnetic storms are irregular disturbances of the magnetic field that may last a few minutes or several days. One such storm caused a variation in declination of 5° in a period of 14 minutes at Cheltenham, Md. The same storm caused a variation of 9¼° in 1¾ hours in Saskatchewan.* The ordinary magnetic storm does not effect the declination more than ½°. An investigation† of the observations on 18,000 consecutive days at the Kew Magnetic Observatory in England gave the following results:

Undisturbed days	12%
Days having a change of less than 10′ in declination	66%
Days having a change of 10′ to 30′ in declination	20%
Days having a change of 30′ to 60′ in declination	1.6%
Days having a change of over 1° in declination	0.4%

SIGNIFICANCE OF THE ARRANGEMENT OF LOCAL MAGNETIC ATTRACTION

The effect upon the general field of the earth of the presence of rocks containing magnetite is shown in figure 6, page 49, and figure 16, page 74. This local attraction is more or less irregularly distributed. Along the strike of a magnetic formation it may be strong in some places and weak in others, but nevertheless the attractions observed on successive traverses will in many cases fall in a line which shows the general strike of the formation. Due to the usual massive character of igneous rocks, the distribution of the local attraction is not so regular as it is in bedded rocks. It is sometimes possible for an experienced observer to distinguish with a fair degree of certainty whether the given attraction is due to a magnetite-bearing igneous rock, or to a sedimentary rock such as iron formation.

The expression "a magnetic line of good characteristics" is often used in this report. By this is meant a line of moderate attractions —usually varying less than 10° from the dip needle normal—with a single maximum from which the attraction decreases steadily on

* Terrestrial Magnetism, Vol. XIV, pp. 179 and 185.

† Philosophical Transactions, Vol. 20.

both sides to the normal. There are all graduations from good to poor magnetic lines and it is often difficult in practice to draw a sharp distinction.

When by careful magnetic observations, either with or without the aid of outcrops, an iron-bearing formation has been traced out, it is not at all certain that iron ore exists in commercial quantities. The only way of definitely proving the existence of ore in a formation thus traced out is careful exploration by test pitting or drilling in favorable places along the general belt indicated by the magnetic attraction. Brooks' statement that "when attraction has been found, the chance of ore is not more than 1 to 50,"* is highly optimistic if considered as applying to a single drill hole or test pit, but it is pessimistic when applied to a long belt of attraction. The chances are probably better than one in five that merchantable ore exists along the line of magnetic attraction if it is many miles in length, and has good characteristics.

The relation of the maximum local magnetic attraction to the occurrence of ore is exceedingly variable. In some cases it happens that the base of the iron-bearing formation shows the greatest degree of attraction and that the workable ore deposits lie stratigraphically above the line of the maximum attraction. In other cases this may be reversed. In still other cases the strongest local attraction may be directly over the ore deposit. These relations vary with the character of the ore. A magnetite ore body would itself always show the greatest local attraction. A body of hematite ore might be the cause of the maximum local attraction due to the presence of magnetite in it, or the magnetite might be present in larger amounts in parts of the formation away from the ore.

In the Lake Superior region it is generally true that magnetic attractions of *very great strength* are not found immediately over large bodies of hematite. There are some notable exceptions to this, such as the Chapin mine at Iron Mountain, but it is believed that the statement will hold true in a large majority of cases. *However, there is no iron range in the Lake Superior district which does not show at least mild attractions on or near the iron formation. These attractions have been, in nearly every case, of much value in delimiting the range and indicating favorable places to explore.*

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* Michigan Geol. Survey, 1873, Vol. I, p. 220.

These statements indicate the great importance of the slight variations in the earth's magnetic field which are frequently found in association with the parts of iron-bearing formations that have been oxidized and enriched. The importance of these slight attractions has been well exemplified in recent years by the discovery of important belts of iron-bearing formation in the Cuyuna District of Minnesota, where the deflections of the magnetic needle which indicated the presence of the richest belts were only a few degrees different from the normal.

INSTRUMENTS AND THEIR USES

The instruments ordinarily used in making magnetic observations in the Lake Superior region are the dial compass and dip needle. While these instruments are quite simple, their successful use and the intelligent interpretation of the results obtained require a detailed knowledge of their principles and construction, and very careful handling.

THE DIAL COMPASS

General Description.—It is interesting to note that the dial compass was devised by Maj. T. B. Brooks and Prof. R. D. Irving in their work in the Florence and Gogebic ranges. The dial compass consists of an ordinary surveyor's compass and a 2½″ needle. On the north side of the instrument there is an upright provided with a sight slit, and at the proper height a hole through which a thread is passed and fastened in an eye at the south side of the compass. around the outer edge of the compass is the hour circle. The graduated circle from which the needle is read is movable, and the normal declination can be set off so that the local variation of the needle, which is due to magnetic rocks, will be read from the normal declination of the needle rather than from true north.

The dial compass is used to show two facts regarding the magnetic field; the direction of the horizontal component at the point of observation, and in approximate fashion, its relative horizontal intensity.

Principles of the Instrument.—As its name indicates, the dial compass is a portable sun dial. In the ordinary sun dial the edge of the gnomon is parallel to the axis of the earth, and likewise in the dial compass the indicating thread must be set at such an angle that it also will be parallel to the axis of the earth when the compass is set in a N-S line. This angle varies with the latitude. At the north pole (latitude 90°) the thread would have to be vertical (90° from the horizon), and at the equator (latitude 0°) the thread would have to be horizontal (0° from the horizon). The angle between the compass plate and the thread must be equal to the latitude of the place where the dial is to be used. The graduations of the hour circle also will vary with latitude, and the instrument makers therefore provide circles for each half degree.

There are three essential elements to the sun dial—the position of the sun, the position of the gnomon, and time. Time is the particular element sought from the sun dial. In the dial compass we use two of the elements, known time and the position of the sun, to set the thread in the correct position pointing toward the north.

Time Correction.—In using a watch to get the time for the running of the dial compass, it is necessary to make corrections to standard time to get the local sun time.

True solar (apparent time) and *mean solar* are the two kinds of time we must deal with in running the dial compass. *Mean solar* time is that in ordinary use. In this the year is divided into equal parts, and all mean solar days are exactly the same length. A *true solar* day is the time between two successive passages of the sun across the zenith. On account of the elliptical shape of the earth's orbit and its inclination to the earth's axis these true solar days vary in length, a day in December being nearly a minute longer than one in September. The accumulation of these differences may make the time of the passage of the sun across the zenith (noon by *true solar* time) as much as 17 minutes earlier or later than noon according to *mean solar* time. This difference between *mean solar* time and *true solar* time is known as the "equation of time," and is given for each day of the year in the American Ephemeris issued by the Navy Department and in small memorandum books issued by the makers of instruments. In the United States standard time is the *mean solar* time of the meridians of 75°, 90°, 105° and 120° west longtiude. Central time is the time of the meridian of 90° and in this time zone all of the Lake Superior iron region lies. This is the time used by railroads and jewelers. Since the apparent travel of the sun about the earth is 360° in 24 hours, one hour represents a travel of 15°. Thus when it is 12 o'clock noon at Greenwich, it is 6 A. M. on the 90° meridian.

Local standard time is *mean solar* time for the particular locality considered and differs from central time for all places not on the 90° meridian. The longitude of Ladysmith is about 91°5′ west or 1°5′ west of the standard meridian of central time. Since 15° represents one hour's travel of the sun, this 1°5′ represents 4.3 minutes and local standard time (or *mean solar* time) for Ladysmith is therefore 4.3 minutes slow. When it is 12 by central standard time, it is 11:55.7 by local standard time.

Local standard time agrees with true solar time only four times during the year. During some parts of the year the sun is ahead of standard time and at other parts of the year it is behind standard time, the change taking place constantly and the difference being given by the "equation of time." When the sun is faster than local standard time, the equation of time must be added to local standard time to give true solar time. When the sun is slower than local standard time, the equation of time must be subtracted from local standard time to give true solar time. This *true solar* time (the "apparent time" of the ephemeris) is what must be used with the dial compass. The equation of time for 1914 is plotted as a curve in figure 8. This shows the magnitude and rate of change of the equation of time for that year. It will be noted that the change is most rapid in December and January, when it is about 3 minutes per week, and the greatest maximum values are reached in February and November.

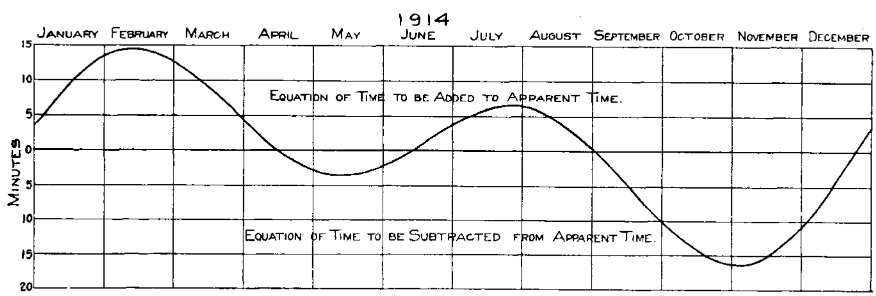

Fig. 8. Curve showing equation of time for 1914. This shows the difference between true solar time and mean solar time.

As an example of the method of applying the equation of time, we will suppose that the *true solar* time (apparent time) is desired for the longitude of Ladysmith on August 27, 1914. If we look on the page for August in the 1914 ephemeris, we find the following:

August, 1914	Equation of time to be **added** to apparent time
Thursday, 27	1 minute, 38.2 seconds
Friday, 28	1 minute, 21.12 seconds
Saturday, 29	1 minute, 3.64 seconds.
Sunday, 30	45.78 seconds
Monday, 31	27.56 seconds

The column giving the equation of time shows the time to be added* to *true solar time* to give local standard time (mean solar time). However, we already have the local standard time, which we have found to be 4.3 minutes slower than central standard time, and want to find true solar time. Since this is the reverse of the procedure in the table, instead of adding we subtract the 1 minute, 38 seconds given as the equation of time for August 27th to get true solar time; or, instead of subtracting the 4.3 minutes from central time to get local standard time we subtract 6 minutes from central time to get true solar time, the time we use with the compass.

The time used in running a dial compass should be corrected as often as the change in the equation of time makes a half minute difference. In spring and fall when the change in the equation of time is rapid, it amounts to two minutes or more in a week. The best way to correct the time is not to change the watch but to use a correction table as explained on page 64.

It is necessary to have a very accurate watch if time is to be carried for a very long period without opportunity of correcting it. It is sometimes necessary to go many weeks without being able to check the watches with standard time. It is quite necessary, therefore, to be able to determine in camp that the time is correct. The simplest way is to set a dial compass on the north-south line (determined by an observation of Polaris) and check the time before starting to work each morning. This will detect an error of a minute, which is usually satisfactory for dial compass work, but it necessitates staying in camp until the sun is well up in the sky and therefore wastes too much time.

* In this month the equation of time is added. In October it would be subtracted, as stated at the head of the column for that month.

A better and more accurate way to test the watches is to observe the time of setting of some particular star. Before leaving the railroad station for camp the watch should be set exactly on standard time. The first evening in camp a spike or a large nail should be driven into some tree or firm post so that it projects in as nearly horizontal position as it can be set. A stick may be used in place of a nail. This horizontal stick or nail, together with some other fixed point such as a readily identifiable projection on the horizon, a chimney top, or even another horizontal stick nailed to a tree 100 or more feet away, will make a plane of sight. At about ten o'clock that night some easily recognizable star near this plane should be selected and watched until it sinks across the plane of sight. The time when it crosses this plane should be noted. Each succeeding night it will cross this plane 3.93 minutes earlier. If it crossed at exactly 10 o'clock the first night it will cross at 3.93 minutes before 10 o'clock the second night. In a week it will cross at 7x3.93 minutes or 27.51 minutes before 10. This gives very exact time with which the watch can be compared as often as desired. To avoid possible difficulties on cloudy nights it is advisable to have the time of several stars.

Sources of Error.—From the discussion of time corrections it is apparent that errors in the time used with the dial compass will make the observations incorrect. Five minutes error in time will make the readings of the declination about two degrees in error. There are also a number of sources of error in the instrument as ordinarily manufactured and adjusted. These are as follows:

1. The level bubbles may not be parallel to the compass plate and consequently the compass will not be horizontal when the bubbles are levelled.

2. The angle of the thread with the compass plate may be incorrect for a number of reasons. The upright on the north side of the compass may not stand vertical, either because the joint is not correctly made or because the string is too tight; the hole for the string may not be directly above the noon mark on the hour circle, or may be at the wrong elevation; and the loop to which the thread is attached at the south side of the compass oftentimes permits of a noticeable vertical variation of the thread.

3. The string may not be put in properly so that when the standard is erected it is not pulled up tight enough to straighten it out.

4. The hour circle may be incorrectly divided.

These sources of error are considerable in amount in many instruments. Their magnitudes can be determined by setting up the instruments on a north-south line, determined in one of the ways described later, and observing the time indicated by the compass each half hour throughout the day. The time shown by the compass will often differ several minutes from that computed from the ephemeris, enough in many cases to make it possible to get consistent, accurate results with the dial compass by using only the time corrections from an ephemeris. In order to make observations that can be depended upon to show small differences on local attraction, it is necessary to make a correction table by observing the time given by the compass set up as indicated.

Other sources of error that need to be mentioned are magnetic storms (not thunder storms, but disturbances of the earth's magnetic field), and the electrification of the glass over the compass. This latter, particularly in cold weather, is often sufficient to seriously disturb the needle. It is good practice to breathe on the glass frequently on cold days to remove any electric charge that may be present.

Establishing the Meridian.—An observation of Polaris is the simplest and most accurate method of obtaining a meridian or true north and south line, since the axis of the earth points toward the center of the orbit of Polaris. The elongation of Polaris is explained in *B*, figure 9.

Method 1.—This method is perhaps the better one, since stormy weather, a hazy atmosphere, or the presence of clouds may interfere with or entirely prevent observation when the star is either at elongation or on the meridian (method 2) and both events sometimes occur in broad daylight or at an inconvenient hour of the night. By this method Polaris may be observed at a convenient time and the meridian calculated. The time when Polaris is at eastern or western elongation on any date may be obtained by interpolation from the ephemeris. For our purposes this table can be used directly (without latitude and longitude corrections). Polaris is easily located since the stars on the outer side of the Great Dipper, Alpha and Beta, *C*, figure 9, are almost directly in a line with Polaris and distant from it about 5 times the space between themselves. During daylight on the day of the observations, select a level spot where an unobstructed view of the north may be obtained. Select this site also with the idea in mind that 200 paces of clear space in a north-south line will be needed to correct compasses. Suspend a stone or plumb bob by a cord about 20 feet in length. A limb of a tree, a crotch, or stiff pole between two trees, serves well as a place of suspension. If a wind is blowing, suspend the bob in a pail of water.

These preparations made, all is ready for the observation as soon as it is dark. A light should be used to illuminate the plumb line

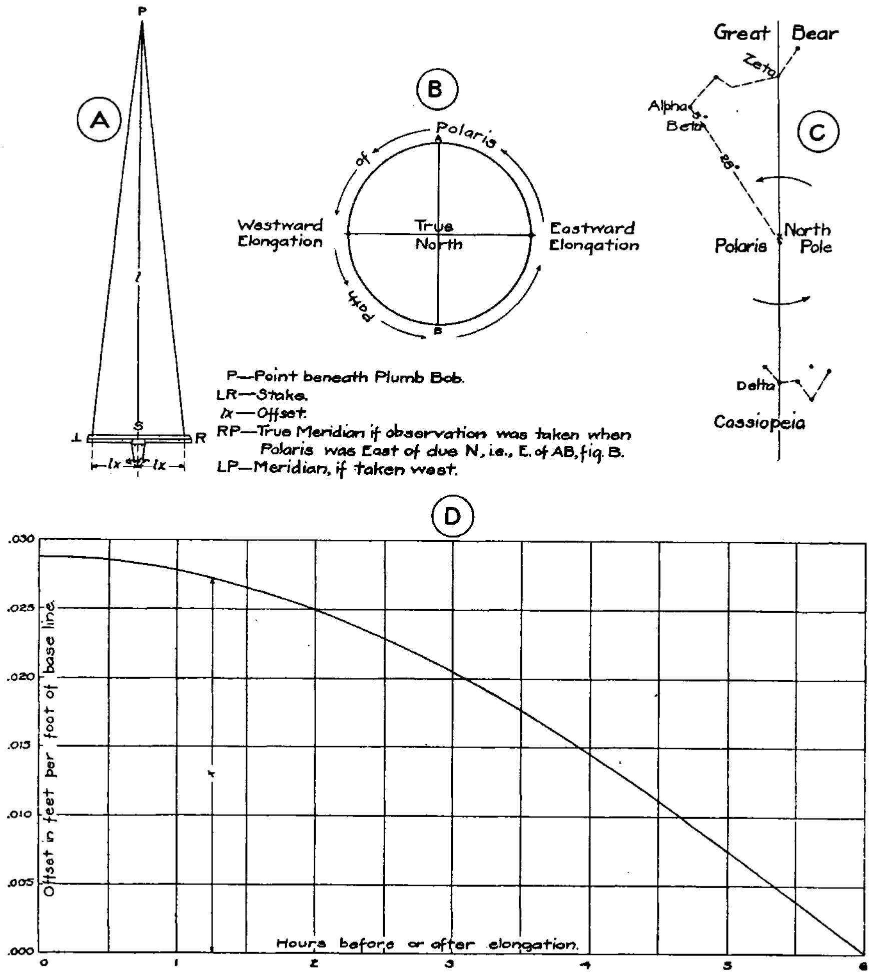

FIG. 9. Diagrams illustrating methods of getting a true north-south line.

just below its support, care being taken to obscure the course of light from the view of the observer.

To make the observation set a 2-foot picket, with a horizontal piece nailed to it as shown in *A*, figure 9, in line with the plumb line and Polaris. Drive it firmly into the ground and set a pin exactly in line with the star and the plumb line, be sure the picket is firmly in the ground and will not spring out of line. Note the exact local standard time. From the ephemeris determine the time of elongation which is nearest the time of observation. Find the exact length of time the observation was taken before or after elongation. Using this time, determine from the curve, *D*, figure 9, the correction or offset, *x*, for each foot of the base line, *l*. The total offset is *lx*. Set off this distance at right angles to the line *P S, A*, figure 9, to the east of *S* if Polaris was observed within 6 hours of eastward elongation; and to the west of *S* if the observation was within 6 hours of westward elongation. Having made this offset, set a pin at point *R* or *L*, as the case may be. Then sight over the points *RP* or *LP* and extend the true meridian to a distance of at least 200 paces, setting solid stakes to mark the ends of the line, and you are ready to make the compass corrections. Illustration:

Date, July 25, 1914.
Station, Lat. 45° N., Longitude 90°30′ W.

Watch time of observation (central time)	8:18 P. M.
Correction to central time for longitude	:02
Mean solar time (local)	8:16
Elongation of Polaris Aug. 1st	10:54.1
Difference of time for 1 day, 3.92 minutes.	
Difference of time for 6 days	:23.5
Eastward elongation of Polaris July 25	11:17.6
	8:16
Time of observation therefore is before eastward elongation	3 hrs. 1.6 min.

From *D*, figure 9

x or offset for 1 ft. of base line for 3 hrs. 1.6 min. is .0205 ft.

lx or offset for 15 ft. of base line is .3075 ft. or 3.68 in.

Since the observation was taken when Polaris was east of due north, the offset 3.68 inches must be made to the east of *S*, and the true meridian is the line *RP*.

Method 2.—To determine the true meridian by observing Polaris at culmination. Figure 9, *C*, shows the principal stars of the constellation, Cassiopeia and Great Bear. As placed, the figure represents relative situations about midnight April 13, 1914, with Polaris at lower culmination and Delta Cassiopeia on the meridian (represented by the straight line) between Polaris and the pole. The diagram held perpendicular to the line of sight directed to the pole, with the right-hand side of the page uppermost, will represent the configuration of the constellations with Polaris near eastern elongation about midnight July 15. Inverted, it will show Zeta of the Great Bear and Polaris on the meridian about midnight October 13.

1. Select that one of the two stars which passes below Polaris at the time of the year when the observation is made. When the star passes the meridian above the pole, it is too near the zenith to be of service. Delta Cassiopeia is on the meridian below Polaris and the pole about midnight April 13 and is therefore the proper star to use at that date and for some two or three months before and after. Six months later Zeta of the Great Bear will supply its place.

2. Using the plumb line and stake, as described in method 1, place the stake in line with the plumb line and Polaris, and move it to the west as Polaris moves east, until Polaris and Delta Cassiopeia appear on the plumb line together, and carefully note the time by the watch; then by moving the stake preserve the alignment with Polaris and the plumb line, paying no further attention to the other star. At the expiration of the small interval of time given below, the nail on the stake and the plumb line will define the true meridian, which may be extended as described in method 1.

For Zeta of the Great Dipper + 8 minutes.
For Delta Cassiopeia + 9 minutes.

Compass Correction Table.—In making a correction table for the dial compass, each compass should be set up and sighted upon some distant point known to be either due north or due south. To obtain such a point an observation on Polaris should be made. After ascertaining that the bubbles are parallel to the plate so that the compass can be properly levelled, the compass should be gone over carefully to note that the string is properly tightened and in perfect condition, that the upright is in its proper position and that the lower end of the thread is in such position that the thread points toward the east-wide line on the hour circle when viewed from the side. Then comparisons of watch and compass time should be made each half hour from 7:30 A. M. to 5 P. M., the period of the day during which the dial compass can be used. It is most satisfactory to select times for comparison when the shadow of the thread exactly coincides with some division of the hour circle and then to observe the corresponding time of the watch. This is more accurate than taking the even minute or 5-minute period of the watch and estimating the minutes and fractions on the hour circle of the compass. A time card like the one shown below is then made for the compassman's use.

COMPASS NO. 1.

Time corrections to be added to watch time to get correct time for compass.

Central Standard Time	August 27, 1911 Correction
8.14	+ 5½ minutes
8.55	+ 6½ minutes
9.59	+ 6 minutes
10.28	+ 6½ minutes
10.58	+ 6½ minutes
11.28	+ 7 minutes
12.36	+ 7½ minutes
1.05	+10 minutes
1.30	+10½ minutes
2.00	+10½ minutes
2.29	+11 minutes
3.00	+10½ minutes
3.30	+10 minutes
4.22	+ 8½ minutes
4.34	+ 8½ minutes

It so happened in this particular instance that the correction at 8.14 was the same as the computed correction to be added to central standard time. If the compass had been free from instrumental errors this same correction would have held for the whole day. Without the use of the correction table the time error would have been 5¼ minutes at 2:30 and the observed declination of the needle would have been wrong by about 2°.

The curves shown in figure 10 were made in 1911 and show the variation of the compasses in the Florence district. These curves are given for different compasses to show the variation of individual instruments, and for different times of the year to show how the same compass will change as threads are renewed and as the difference between local standard time and sun time changes. It should be borne in mind that if there were no instrumental errors these curves would be straight horizontal lines.

A new correction table should be made whenever it is necessary to insert a new thread or when any other change in the instrumental error is suspected. The table of corrections should be changed

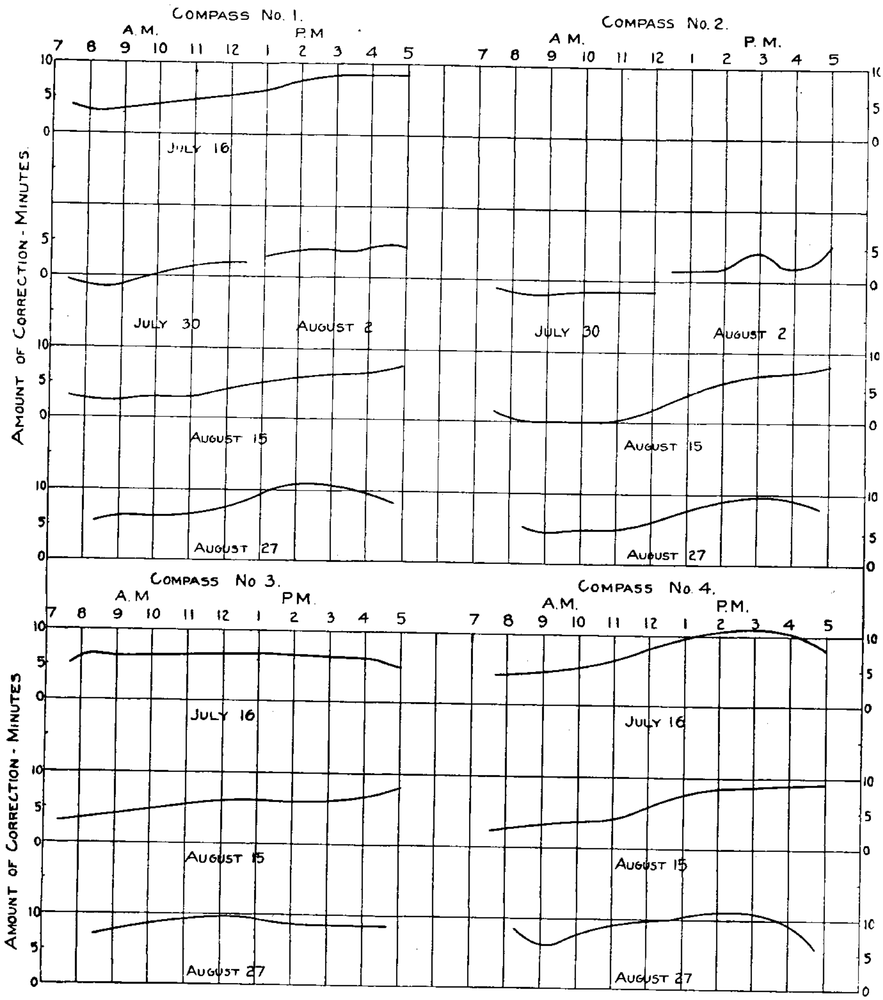

FIG. 10. Compass correction curves showing how different compasses varied on different dates.

from day to day to keep step with the change in equation of time. As an example, consider the table of corrections made for August 27th above. In the ephemeris we find that on August 29th the equation of time has changed 34 seconds and the corrections for

August 27th must be increased by that amount. On August 31st the equation of time has changed 1 minute, 10 seconds from its value on August 27th, so we increase our corrections by one minute (the 10 seconds being negligible for dial compass use.) This procedure should be followed until a new correction table is made.

General Accuracy.—If a correction table is made with reasonable frequency, and if the compass is kept in good condition, the readings of the declination should be accurate within ½° in good circumstances, and with the rare exceptions of unusual magnetic storms the error should never be more than a degree.

THE DIP NEEDLE

General Description.—The dip needle consists of a thin, light, magnetic needle swung on a pivot, the ends of which rest in jewelled cups. If the pivot were exactly in the center of gravity and the bearings were frictionless, this needle, when in the plane of the magnetic meridian, would show the exact inclination of the magnetic attraction at the point of observation. One form of dip needle (the Norwegian) is provided with a universal joint which permits it to swing in all directions. This form, however, has not met with as much favor in the Lake Superior iron country as the ordinary form with fixed bearings which can swing only in one plane.

There are two forms of dip needles with fixed bearings, depending on the way in which the counterweight is applied. In the ordinary form it is applied near the south end of the needle and is symmetrically placed with regard to its long axis. The Gurley instruments of this form are balanced so that the needle is horizontal and reads zero at Troy, N. Y. This form is always held so the needle is in the plane of the magnetic meridian. In the second form the counterweight is applied underneath the pivot (on the short axis of symmetry) and this form is usually (though not necessarily) observed in a position perpendicular to the plane of the magnetic meridian. When held thus its position depends only upon the variation in intensity of the vertical component of the magnetic field. The position assumed by either form of needle, when held parallel to the meridian, depends upon both the horizontal and vertical components of the magnetic field.

The difference in action of the two forms lies in the fact that the turning effect—the turning moment—of the counterweight increases with increase in dip of the needle in the form having the counterweight below and decreases with the increase in dip in the ordinary form.

The dip needle is more sensitive than the dial in detecting small changes in the earth's field. As ordinarily used it gives no information as to the direction or intensity of the earth's field. Its readings are most useful to compare with other readings of the same instrument, or of instruments having approximately the same normal reading.

The construction of the dip needle is necessarily delicate and this makes it very difficult to keep in good condition. It is hard to prevent moisture and dirt from getting inside the case, and once inside they are very likely to get into the jewelled bearings. The moisture causes rust pits in the ends of the pivots, destroying the true rounded form necessary for accuracy. The dust introduces friction which very seriously impairs the accuracy of the instrument and "blocks the wheel," as indicated in figure 11, making it impossible to take a series of readings in one spot with an instrument in poor condition without getting occasional differences of as much as 10 or 15 degrees, and oftentimes of 2 to 5 degrees.

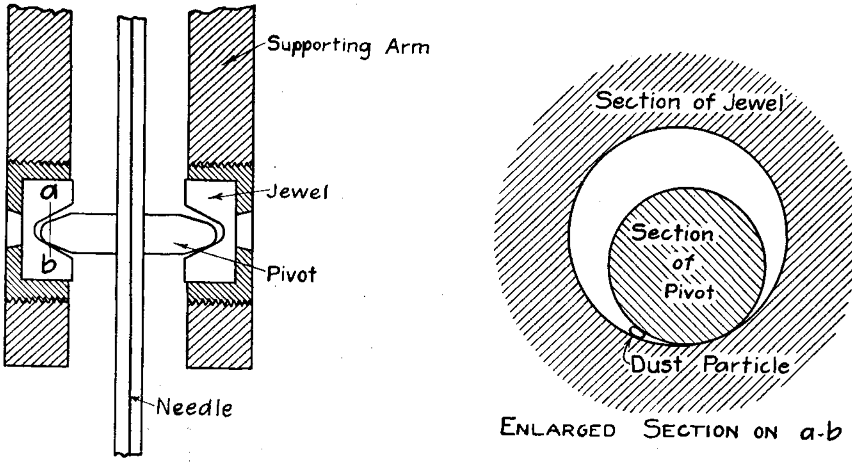

FIG. 11. Enlarged sections showing the action of the dip needle and the effect of dust in the jewels.

This difficulty and the impossibility of definitely interpreting its readings have caused it to be relied upon somewhat less than the dial compass until recent years.

Principles of the Dip Needle.—In order to use the dip needle intelligently it is necessary to understand its construction and the principles on which it acts. There are two constructional features that are of great importance. The first of these is the mounting—the way in which the pivot acts in its bearings. The manner in which the pivot rests in the jewels is indicated by figure 11. It appears from this figure that it is not a needle-point bearing, as in the horizontal compass, but there is more or less rolling movement in the action of the needle. This feature is exaggerated in the figure to make it more easily appreciated. The nearer the point of the pivot comes to being a true point, the better and more sensitive is the dip needle's action.

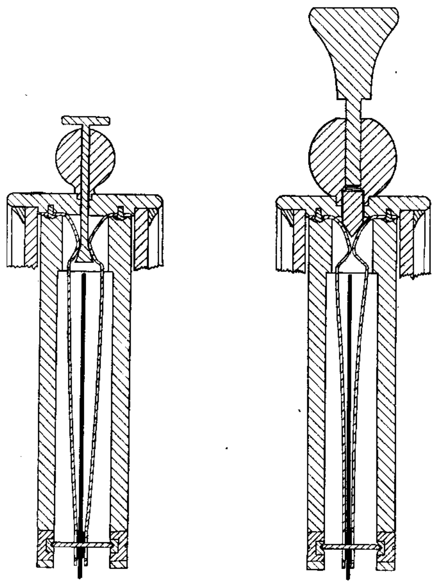

FIG. 12. Old (left) and new (right) methods of operating the clamps that hold the dip needle from swinging when not in use.

The second constructional feature is the manner in which the needle is stopped from swinging. This is done by two brass clamps with holes through which the pivots pass. To free the needle these are pulled apart by a wedge which is raised by a small button. This button is pushed down to drop the wedge and allow the brass strips to pinch the needle and stop it. In use dirt accumulates about the tiny rod connecting the wedge and the button so that it sticks, and the wedge goes down with a snap which allows the clamps to batter the pivot ends into the jewels. This battering soon dulls the pivot points and destroys the delicacy of the instrument. To avoid this difficulty, as well as to provide a better means of holding the instrument and to prevent dirt and moisture from getting inside the case, a new method of operating the clamps by a screw was devised and used in the area covered by this report. This was much more satisfactory than the old form. The two forms are shown in figure 12.

In addition to the two constructional features described above it is necessary to understand the effect of the counterweight and of magnetic fields of different intensity and inclination. The position of rest assumed by the dip needle is dependent upon three factors: (1) the weight and position of the counterweight, (2) the inclination and (3) the intensity of the magnetic force. The two forces act at a distance from the pivot of the needle. The counterweight is at the distance *a* and tends to pull the south end of the needle downward. Its turning moment is the product of the weight and the effective distance from the pivot. From figure 13 it is apparent that the moment is *cy*, that *y* decreases as the needle departs from a horizontal position when the counterweight is on the south end, and that *y* increases as the needle departs from the horizontal when the counterweight is below the needle.

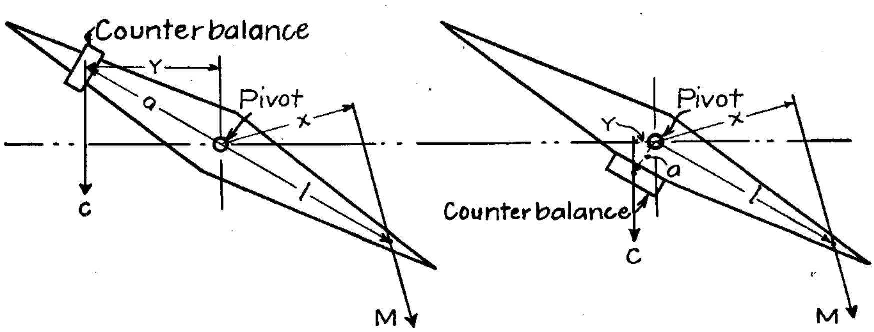

FIG. 13. The two forms of dip needle, one with counterweight on the end and the other with the counterweight below the needle.

The turning moment of the counterweight is opposed to the turning moment of the magnetic force. The magnetic field pulls upward on the south end and downward on the north end of the needle. For convenience these forces are shown in figure 13 as the singe force *M*. The magnitude of this force depends upon the distance—2l—between the poles of the magnetic needle, its pole strength m (the product $2lm$ being the *magnetic moment* of the needle) and the strength of the earth's field H. The force M shown in the figure is the product $2lmH$. The turning moment of this force is Mx, and it tends to pull the *north* end of the needle downward. The turning moment of this force is evidently greatest when the needle is directly across the earth's field and $x = l$.

For a needle which has a normal reading 12° below horizontal in the normal field at Madison (Intensity = .75 gauss, Inclination = 76°) the counterweight was weighed and found to be 22 milligrams. The distance a was measured and found to be 1.9 centimeters. With these constants known it was possible to compute the moment of the counterweight for any position, and hence the moment of the force M needed to balance it. Conversely it was possible to compute a counterweight for this needle which would give any desired reading for any field selected.

From these data a series of curves, figure 14, were drawn. These show the positions this particular needle would assume for all variations of the intensity from 0 to 1.4 gausses, and for angles of inclination varying by 5° intervals from 65° to 90°. The ranges of angle and intensity were chosen to include all intensities and all degrees of inclination ordinarily found near magnetic formations. The curves in A show the dip needle readings when the needle is counterbalanced so as to have a reading 12° below horizontal in the normal field at Madison, and those in B are for the same needle with a normal reading of 12° above horizontal—nearly at right angles to the direction of the earth's field.

These curves give a complete and definite picture of the behavior of the ordinary dip needle under the conditions usually met with in the field. From A it appears that a positive dip of 20° may be due to any inclination of the field from 65° to 90° but cannot indicate an intensity greater than .91 or less than .69 within that range of inclinations.

In the space included between the dips of + 2° and — 24° the change in the dip needle reading is about 12° for a 10% change in the intensity, and an equal amount for a 20° change in the inclination of the earth's field. Thus 10% change in intensity may be said to be the equivalent of 20° change in inclination so far as effect upon the dip needle is concerned. The intensity changes found in areas of local attraction vary 10 times this amount and the total change in inclination ordinarily found is probably less than twice 20°. Thus for ordinary fields the changes in *intensity* may be said to have at least 5 times the effect of changes in *inclination* upon the dip needle readings.

From the curves it is apparent that the dip needle is most sensitive to intensity changes near the center where the curve approaches a horizontal direction. Toward the ends of the curve

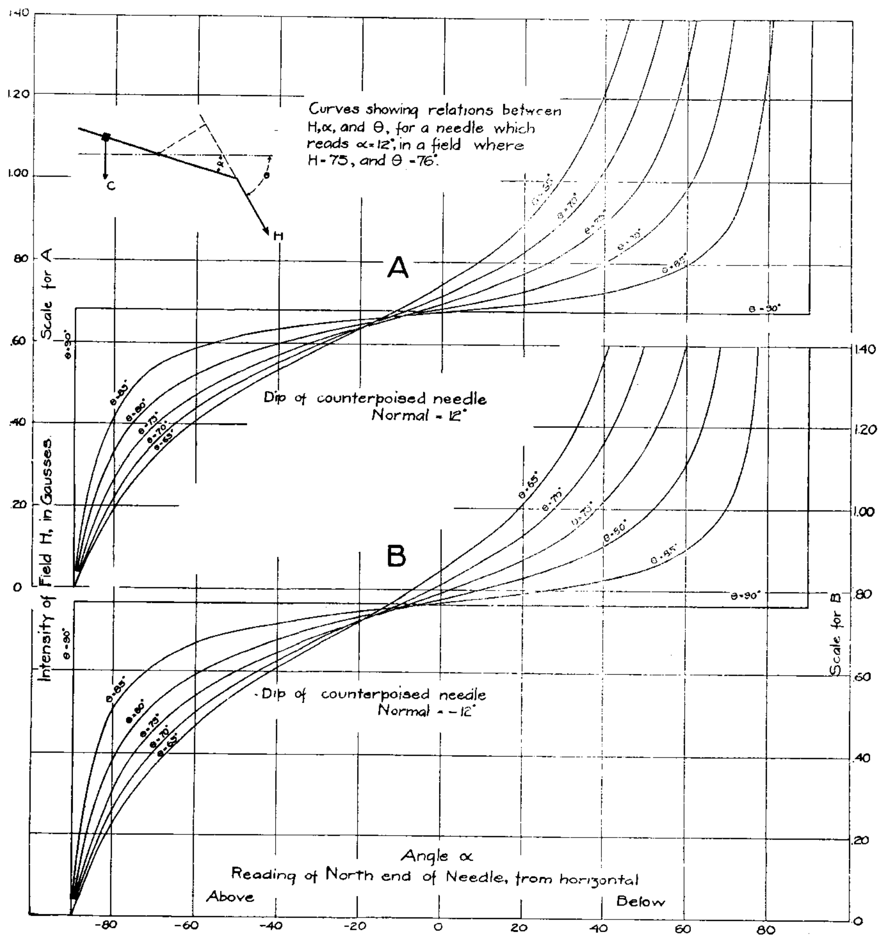

FIG. 14. Curves showing position assumed by two dip needles with different counterweights for various intensities and inclinations of the magnetic field.

the change in inclination has a relatively greater effect. From a comparison of curves *A* and *B* it is evident that there is comparatively little difference in slope of the curves for the differently counterweighted needles, but that the slight difference that does exist favors the needle whose normal is 12° below the horizontal —the *A* curves. Therefore the needle with the 12° normal should be slightly more sensitive than one with a normal of 0°, or — 12°.

Figure 15 shows graphically the effect upon the dip needle of changes in intensity and inclination. In this figure the turning moment of the counterweight is represented by a force acting upward at the point where the force *M* acts downward. The moment of the counterweight varies with the position of the needle as indicated. The position assumed by the needle is the one in which the two turning moments exactly counterbalance each other, or, in other words, the position in which the resultant of the two forces passes through the pivot and so has no lever arm and no turning effect. Intensity is indicated by the lengths of the lines *M* representing the magnetic force, and inclination is represented by their directions. The needle at the left shows the effect of change of inclination with no change in intensity, and that at the right shows the effect of change in intensity with no change in inclination.

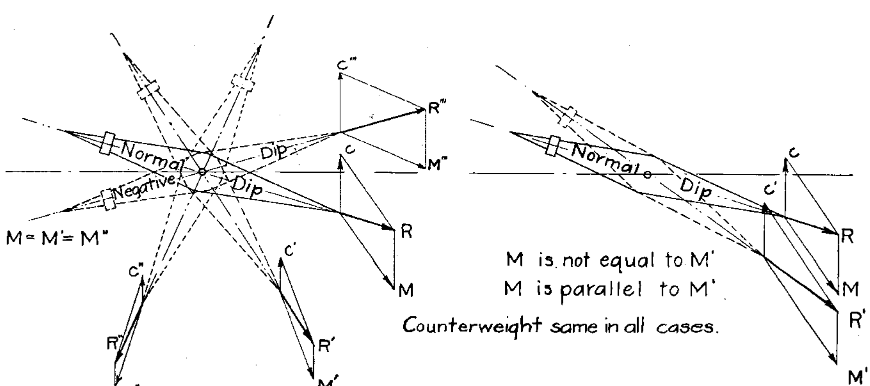

FIG. 15. Showing the effect upon the dip needle of changing the inclination leaving intensity constant (left); and of changing intensity, leaving inclination constant (right).

A general idea of the positions assumed by a dip needle in crossing a strong magnetic formation is given in figure 16. In this figure the dip needle is represented by the heavy arrows. The vertical arrows represent the effect of the counterweight which tends to pull the north end of the dip needle upward. The lower arrows represent the inclination and intensity of the earth's magnetic field at each successive point of observation. The figure explains why two positions are sometimes found in which the needle will dip 90°.

Another important deduction from the curves of figure 16 is that negative readings—those in which the north end of the needle goes above its normal position—are due almost entirely to lowering the intensity of the field. It is very doubtful if there exists in the Lake Superior region a magnetic formation whose effect would be strong enough to reverse the direction of the earth's

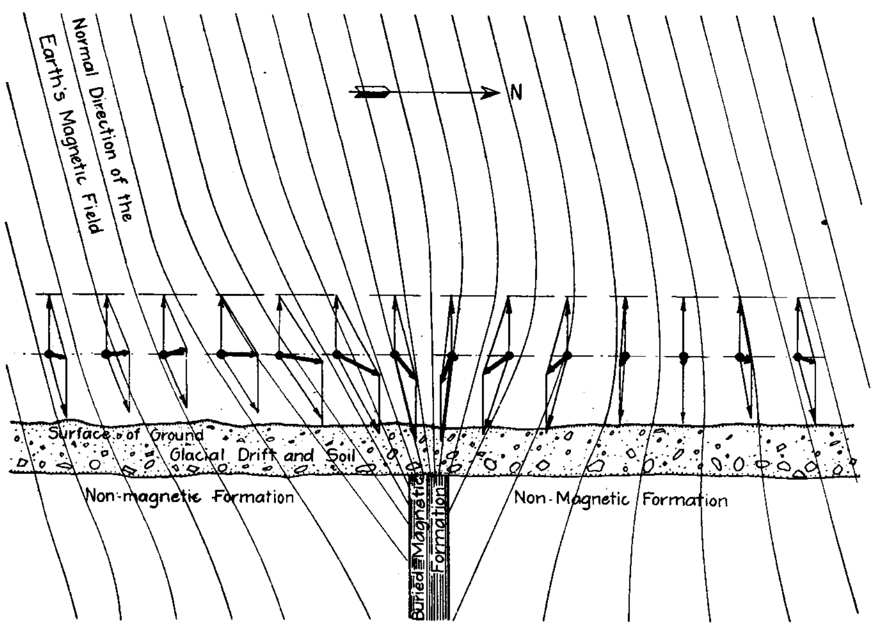

FIG. 16. The positions which the dip needle (represented by the heavy arrow) takes in going over a strongly magnetic formation. Each position is the resultant of the vertical, upward pull of the counterweight and the (usually) inclined, downward pull of the magnetic field.

field (and so actually attract the south pole of the needle and repel the north) except for distances of a very few feet. If such a case were found the dip needle would behave as it would in a normal field if the counterweight were on the *north* end,—in other words, it would come to rest in that small part of the circle lying between the *inclination* direction and the nearest vertical.

The discussion of figure 14, it should be remembered, applies specifically to the one needle whose magnetic moment and counterweight were determined. As manufactured these needles vary more or less in both constants. It is therefore important to consider the effect of these individual variations.

The relative magnetic moments of needles can be determined as described under the succeeding head. Differences in the behavior of apparently similar needles can usually be understood from such a comparison. Figure 14 shows how needles with different counterweights and the same magnetic moment may give widely different readings for the same change in magnetic field. Varying the magnetic moment changes the magnitude of the force H in the figure so that by this method the *A* curves could be altered to fit the *B* curves.

If two similar needles with different magnetic moments have their counterweights so adjusted as to give the same normal reading they will be effected in the same degree by changes in the earth's field.

Determination of the Relative Strengths of Magnetic Needles.—In the field use of the dial compass and dip needle it is sometimes desirable to know whether the magnetic needle of a particular instrument has lost any considerable part of its strength. A very simple method of doing this is to set first one and then the other of the needles to be compared in the position *N-S* in figure 27, page 97, and a sensitive dial compass with the needle swinging free, in the position *n-s*. The distance between the centers of *N-S* and *n-s* should be exactly the same in each instance and it is convenient to make it about one foot. If the first needle is placed with one end toward *n-s* it will cause a certain deflection. If the other end is then turned nearest to *n-s* the deflection will be in the opposite direction. Half of the total angle between the two positions is taken as the angle *a* in the formula. The angle *a* is then determined for the second needle of the two to be compared. The magnetic moments, *M* and *M′*, of these two needles then bear the ratio to each other expressed in the formula

$$\frac{M}{M'} = \frac{\tan a}{\tan a'}$$

It is convenient to remember that the natural tangents of angles of 6° or less are directly proportional to the angles and can be found by multiplying the numbers of minutes of angle by 0.00029. Thus the natural tangent of $2° = 120 \times .00029$.

Sources of Error.—Sources of error in dip needle observations are:

1. The manner of holding. It is very necessary that the needle always be held in exactly the same manner, read from the same side, and with the same side of the needle toward the observer. In this work the needle was always read when the observer was facing the east (magnetic) side of the needle.

2. Irregularity in pivot or jewels. If the pivot or jewels are not properly shaped there may be considerable irregularity in the readings obtained. This irregularity can be avoided by testing the instruments carefully and using only those which give consistent results.

3. Dust and moisture on the pivot or in the jewels are evident causes of error, the same in effect as irregularities in pivots or jewels.

4. The gradual loss of magnetism in the needle may make a noticeable difference in readings made at long intervals of time, but the change in a single field season is not likely to be worth considering unless some accident has happened to the instrument.

5. Electrification of the glass from friction, particularly on cold days, is a very common occurrence. It is a good thing to form the habit of breathing on the glass before every observation on cold days to remove any possible charge of electricity that may be present.

6. Magnetic storms will cause variations in the readings, but these will not be consistent in any way and the careful observer is not likely to be misled by them.

Repairing Dip Needles.—Owing to the ease with which the pivots of the dip needles become worn and blunted it was found necessary to devise small repair outfits with which they could be repointed in camp. The chief piece of apparatus was the small lathe shown in figure 17. The glass faces of the instrument were put in with soft wax to facilitate removal. One jewel was unscrewed, the needle removed, and the pivot screwed out of it with a small pair of pliers provided for the purpose. This pivot was put in the chuck and sharpened with a fine hone which rested on the projecting arm. The length of this arm was such as to give the proper angle to the point. After sharpening the point was polished with a piece of very fine emery-powder paper pasted to a flat piece of wood. It was found that a little practice enabled a careful man to put a better point on a pivot than it had when it left the instrument maker. The pivot was then screwed into the needle and inserted in the instrument. The jewel was screwed back into position very carefully so the end of the needle could be moved up and down a barely noticeable distance as the instrument lay on its side. A strong hand lens was used to see that all parts were entirely free of dirt and finger prints. The instrument was then tested to see that it swung freely and gave constant readings when held in the usual manner. If not, the jewels were adjusted until it did. If the normal reading was not satisfactory it was changed by using a very fine file on the brass rivets at either end.

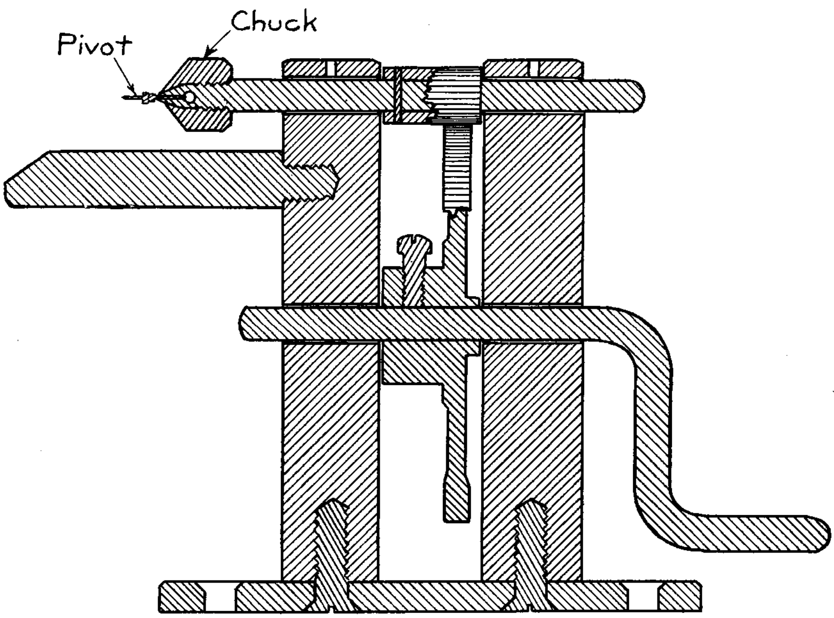

FIG. 17. Small lathe for repairing dip needle pivots. Actual size.

Method of Using.—To get consistent results with the dip needle is extremely difficult and requires intelligent care and use of the instrument, especially if it is desired to detect small variations in the attraction. The dip needle is so likely to get out of order that it must be constantly checked and tested to make sure that it is reading properly. The men who took dip needle readings in this area checked their instruments each morning just before leaving camp and each evening immediately on returning. The observer's complete field outfit, including his collecting bag, hammer, water bottle, and whatever he usually carried in his pockets, was in its usual place and the instrument was always held at exactly the same place in camp and in the same direction. If an instrument failed to give the same dip morning and night it was laid aside to be cleaned and readjusted.

The usual method of holding the dip needle in making observations is by the large bail. However, this is not at all satisfactory if there is any wind, as it is necessary to have the needle quite still while making an observation. With the new form of needle devised for this work the instrument was suspended by the specially formed screw head shown in figure 12, page 69. This proved a very satisfactory means of holding it steady. Level bubbles were provided in all dip needles to make it possible to hold them more accurately.

SIGNIFICANCE OF MAGNETIC OBSERVATIONS

Interpretation of Magnetic Readings.—An excellent mathematical paper on the significance of magnetic observations is published in the Crystal Falls Monograph.* The present discussion is based chiefly on observation and experiment and written with the fact in mind that the average student of geology is not sufficiently familiar with mathematics to understand a mathematical treatment of the subject. Those who wish to study the matter thoroughly should not fail to read Smyth's discussion. Many statements in this chapter are taken from his paper.

In the beginning it may be well to state a few elementary things that should be borne in mind. First, it must not be forgotten that magnetic attraction is seldom uniformly distributed throughout an iron formation. The attraction is always more or less "bunchy," strong in some places and weak in other places, but in developing type cases we must assume, for simplicity, that the attraction of an iron formation is substantially uniform along the strike and leave the modifications to be made by the observer in the field. In the case where the attraction is uniform, its action, considered apart from the earth's field, is always in a direction perpendicular to the line of strike of the formation, as shown in figure 18 after Smyth. The shaded portion inside the circle of radius x is that part of the formation close enough to the observer at A to attract the needle an appreciable amount, and it will be noted that half of the attracting area is on each side of the perpendicular to the strike of the formation. The arrow a

* Mon. XXXVI, U. S. G. S., Chapter 2, Part II, by H. L. Smyth.

represents the north horizontal component, the arrow *b* the direction and intensity of the local attraction (perpendicular to the strike), and the resultant arrow *c* shows the position of the needle, and its length shows the intensity of the resultant.

Second, it will avoid confusion to remember that *at any point there is but one magnetic force, having but a single direction and a definite magnitude*; that while we speak of the horizontal component of the earth's field combining with the horizontal component of the local attraction to give a resultant which is the direction of our horizontal needle, what we really mean is that we are

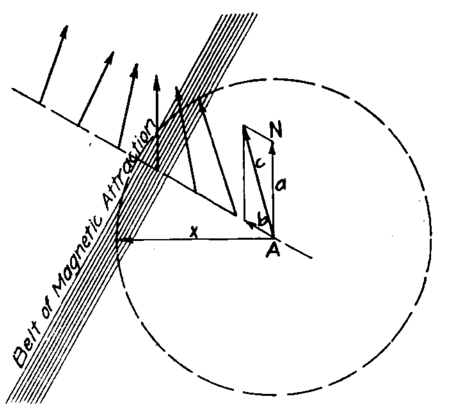

FIG. 18. Showing the effect of a magnetic formation on a dial compass needle at A and successive points in a line across the formation.

dividing up the horizontal component of the single line of force at that point and considering it as two forces for convenience of explanation, viz., the usual horizontal component of the earth's field and a horizontal component normal to the magnetic line. Figure 19 gives a diagrammatic representation of this. The single line of force at any point is represented by the line *MM*. The vertical component of this force is shown by *V*. The horizontal component is the direction assumed by the needle and shown by the force H_R, usually spoken of as the horizontal resultant and divided into two components H_N and H_L, the north component and the local component. It is a common thing to hear persons who have a wrong idea of this insist that their favorite compass is only slightly affected by local attractions—that it will "point true" regardless of whatever local attraction may tempt it from its "straight and narrow path."

With these two things in mind we can proceed to discuss the interpretation of our magnetic readings.

Properly made magnetic observations give us more or less definitely four important items of information:

1. Character of magnetic rock, bedded or massive.
2. The strike of bedded magnetic rocks.
3. The relative intensity of the local attracting force.
4. The direction of dip of bedded magnetic rocks.

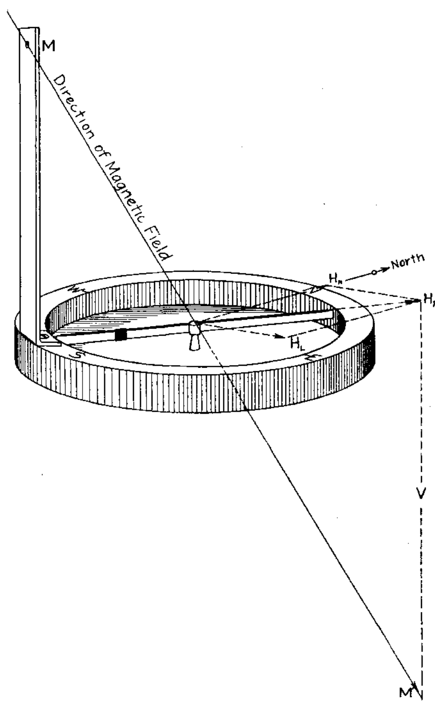

FIG. 19. The components of the earth's magnetic field usually considered are the vertical (V) and the horizontal (HR). The horizontal component is often further divided into north (HN) and local (HL) components.

1. *Character.*—Igneous rocks which show magnetic attraction do not usually possess regular linear structure that persists for any great distance. The magnetic attraction is usually, therefore, much more irregular than that of bedded rocks. This is not always true, however, and other evidence, as outcrops and character of the glacial drift, may be used to verify the indications of the magnetic needle.

2. *Strike.*—From dial compass readings on a single transverse crossing the formation we can correctly infer the general direction of strike of a magnetic formation in all cases except those that are very "bunchy" or that show weak attractions combined with an east-west strike. Figure 20 shows the characteristic difference at a glance. The strike is determined more definitely by connecting on adjacent traverses the points of no deflection on the dial compass curves, or the points of maximum dip needle readings. Such a line is referred to as a *magnetic line.* Traverses should be made across the magnetic formation at intervals close enough to detect all the changes in strike that are desirable for the purpose in mind.

3. *Intensity.*—In the case where the strike is east-west there is no change in direction of the horizontal needle south of the formation so long as the attraction is evenly distributed. Just north of the formation the pull may be strong enough to reverse the needle and cause it to point south for a short distance. If the attraction of the formation is not strong enough to reverse the needle its horizontal component is directly opposed and the intensity is less than normal. It is frequently of value to measure the relative horizontal intensity in such situations, particularly if a dip needle is not used. The period of vibration of the compass needle can be used for this. The normal period of the compass should first be observed in a place known to be free from local attraction. This was found to give, for the compasses used, about eleven swings—half vibrations—in 22 seconds. When the intensity was greater than normal the time of swing was shortened, in some cases to 11 swings in 16½ seconds. When it was less the time was increased. The relative intensity can also be measured in the same manner by observing the time of the swings of the dip needle.

The intensity of the field varies inversely as the square of the period of vibration for swings of small amplitude. There is too much friction in the suspension of the ordinary compass needle to permit a sufficient number of vibrations when the amplitude is small, but in vibrations of large amplitude the error is not great enough to prevent the determination of differences in the intensity that may be very useful in the careful following of magnetic horizons. The following instance taken from the field work in Florence county will serve as an illustration of the use of intensity tests, see figure 21. A magnetic horizon with the usual

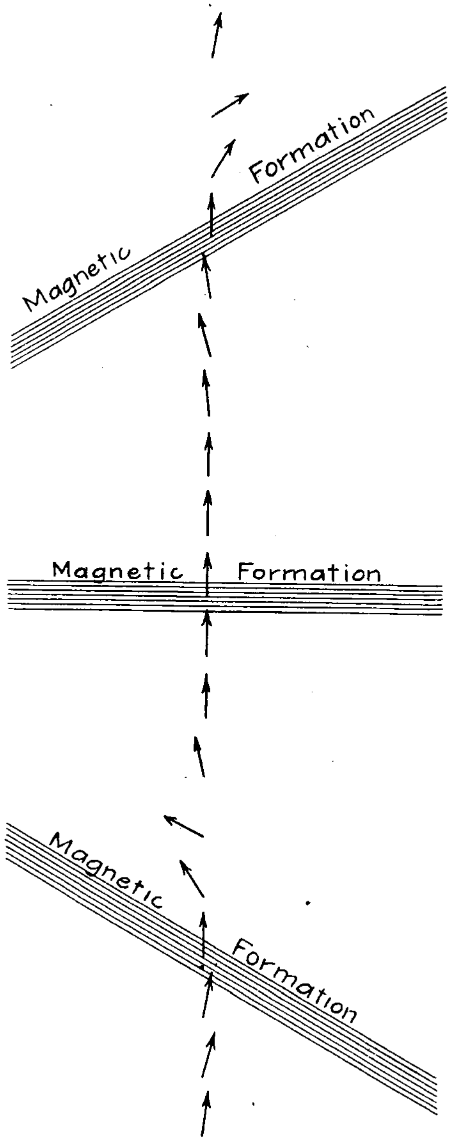

FIG. 20. Showing the effect of the strike of a magnetic formation on the dial compass needle.

northwest strike was being followed by closely spaced traverses. When the compass was northeast of the magnetic horizon, the declination was westward as is the usual case. As successive traverses were made a final one showed a strong westward declination on the east and a strong eastward declination on the west part of a traverse exactly as though a magnetic line had been crossed, but an observation of the period of vibration showed the intensity to be very weak. This indicated that the attracting mass was south of the compass and that the magnetic belt either made a sharp turn from its usual direction or that there was a large magnetic mass located there. Another traverse showed that the line turned sharply and that a fold was the probable cause. An element of geological structure was thus discovered in a district showing no outcrops.

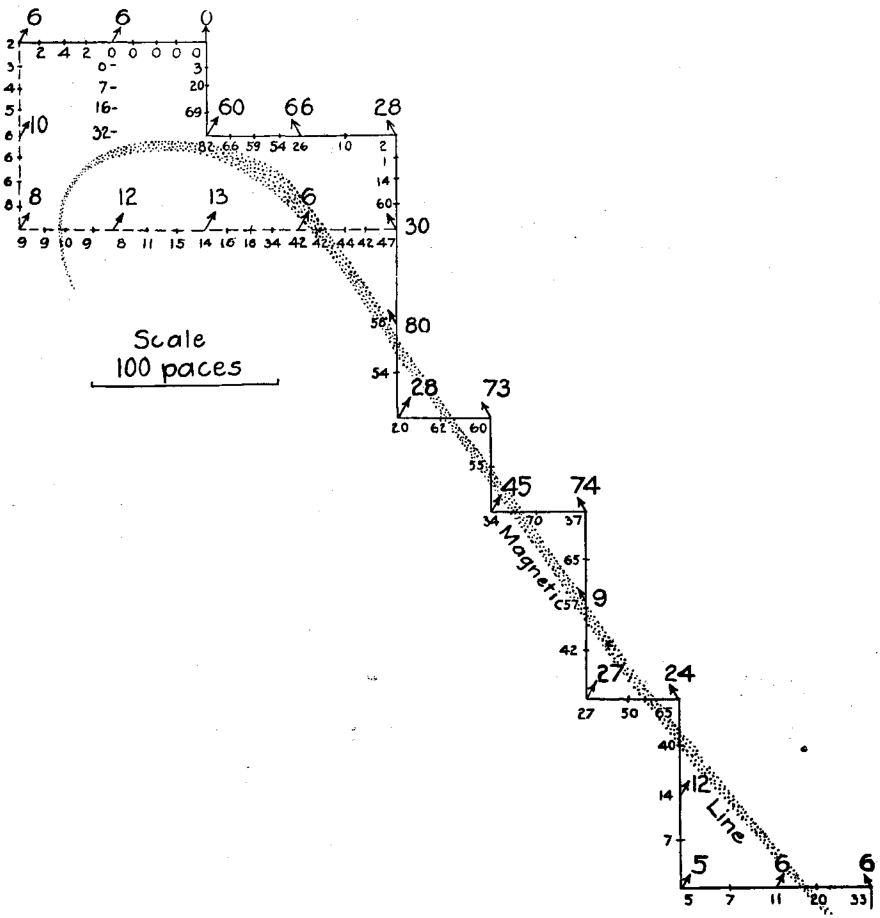

FIG. 21. Map of a magnetic line in Florence County traced by dial compass (large figures) and dip needle (small figures) observations, and showing how its apparent northwest continuation was shown to be wrong by observing the magnetic intensity.

4. *Dip.*—The dip of bedded magnetic rocks has a very noticeable effect on the readings of the dial compass and dip needle, and when this effect can be properly interpreted it is an important aid in determining the structure and in planning explorations for iron ore.

In order to see just what effect various strikes and dips of a magnetic bed would have on the readings of the horizontal needle, an apparatus was constructed with a sheet of heavy tin as the "magnetic formation" and a series of experiments made. The method of procedure as well as the construction, (figure 22) is given so that those who wish to use the results may have an idea as to their accuracy. It was considered that extreme accuracy was unnecessary, as natural conditions in the field are so variable. The accuracy desired was that sufficient to give curves typical of the various dips and strikes.

First a place to conduct the experiment was found—not an easy task in a building—where the direction of the local field did not vary more than one degree in the four feet over which observations were taken. In order to avoid the magnetic effect of nails a single plank of the proper length was used. From the under side of this a sheet of tin 20x28 inches was suspended by a wood frame fastened with copper nails. It could be set at various distances and angles below the surface of the board—the different depths representing different thicknesses of glacial drift covering over a magnetic formation.

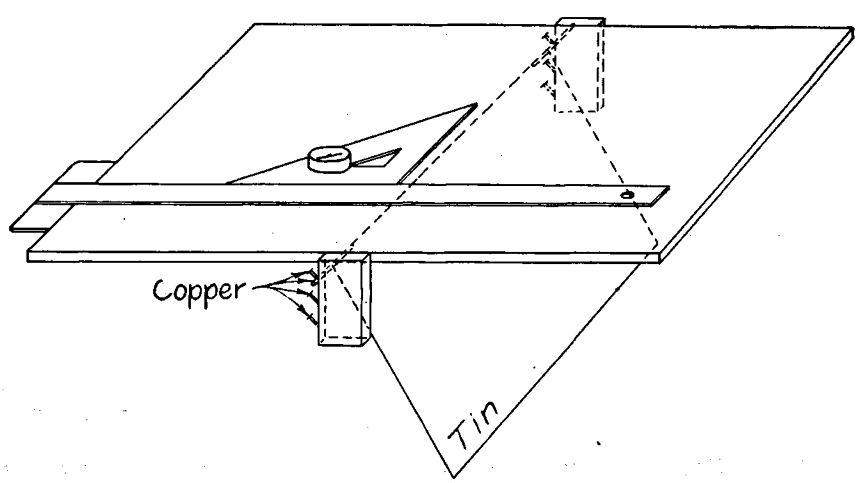

FIG. 22. Apparatus used in testing effect of dip and strike on the dial compass needle. The results are shown in figures 22, 23 and 24.

A long wood T-square was provided, and a small compass, divided to 2° (and estimated to half degree), was fastened with wax to a wood triangle, so that the north-south line was at right angles to its base. The board was oriented so that the "strike" of the tin was parallel to the local magnetic field, and a series of readings was then made by sliding the triangle along the T-square and noting the declination of the compass in many positions. The positions of maximum and zero declinations were very carefully determined by repeated tests. Fifteen series of readings were taken with the tin striking N-S (magnetic) as follows: top of tin 2″ below compass, dips 30° W., 60° W., 90°, 60° E., and 30° E.; top of tin 5″ below compass, same dips; top of tin 8″ below compass, same dips.

Similar series of readings were then made with the "strike" of the tin changed to N. 30° W. and then to N. 60° W. The readings were plotted as curves and are given in figures 23, 24 and 25. The essential relations of the readings are given in tables III, IV and V. Observations for strikes east of north were not made, as it was assumed that they would be similar to those with strikes west of north.

TABLE III.

For Strike N-S.

Dip	Depth	Ratio No. 1 Dist. of E. M.* from 0 / Dist. of W. M. from 0	Ratio No. 2 E. M.* / W. M.
30° W	2″	.62	.68
	5″	.75	.40
	8″	.78	.48
60° W	2″	.81	.89
	5″	.90	.74
	8″	.97	.80
90°	2″	1.08	1.08
	5″	1.40	1.17
	8″	1.14	1.30
60 E	2″	1.36	1.07
	5″	1.11	1.31
	8″	1.18	1.38
30° E	2″	1.95	1.73
	5″	1.39	2.21
	8″	1.14	1.88

*The letters E. M. and W. M. denote the maximum declinations on the east and west sides of the magnetic line. The ratio in the last column gives the relative values of the maxima, and is obtained by dividing the number of degrees of the east maximum by the number of degrees of the west maximum.

TABLE IV.

For Strike N. 30° W.

Dip	Depth	Ratio No. 1 Dist. of E. M. from 0 / Dist. of W. M. from 0	Ratio No. 2 E. M. / W. M.
30° S. W.	2″ 5″ 8″	.64 .72 .92	1.33 .85 .86
60° S. W.	2″ 5″ 8″	.95 .98 1.07	1.78 1.37 1.17
90°	2″ 5″ 8″	1.14 1.20 1.50	1.98 1.84 1.59
60° N. E.	2″ 5″ 8″	1.24 1.13 1.30	2.09 2.03 2.26
30° N. E.	2″ 5″ 8″	1.55 1.42 1.50	1.87 2.45 2.80

TABLE V.

For Strike N. 60° W.

Dip	Depth	Ratio No. 1 Dist. of E. M. from 0 / Dist. of W. M. from 0	Ratio No. 2 E. M. / W. M.
30° S. W.	2″ 5″ 8″	.50 .62 .73	0.87 0.59 0.96
60° S. W.	2″ 5″ 8″	.75 .88 1.15	2.00 1.37 1.54
90°	2″ 5″ 8″	.89 1.20 1.45	4.34 2.17 2.08
60° N. E.	2″ 5″ 8″	1.00 1.13 1.93	4.67 3.33 3.75
30° N. E.	2″ 5″ 8″	1.31 1.36 1.64	4.75 3.31 3.88

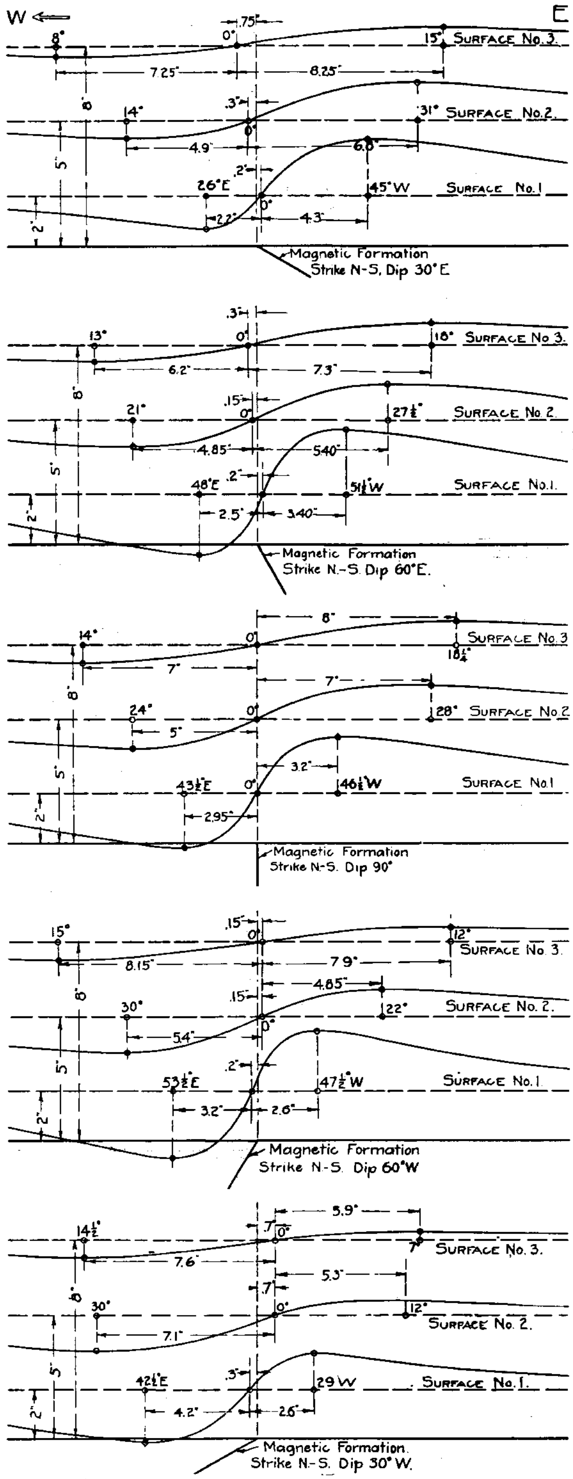

FIG. 23. Dial compass curves for N–S strike with various dips and depths of burial.

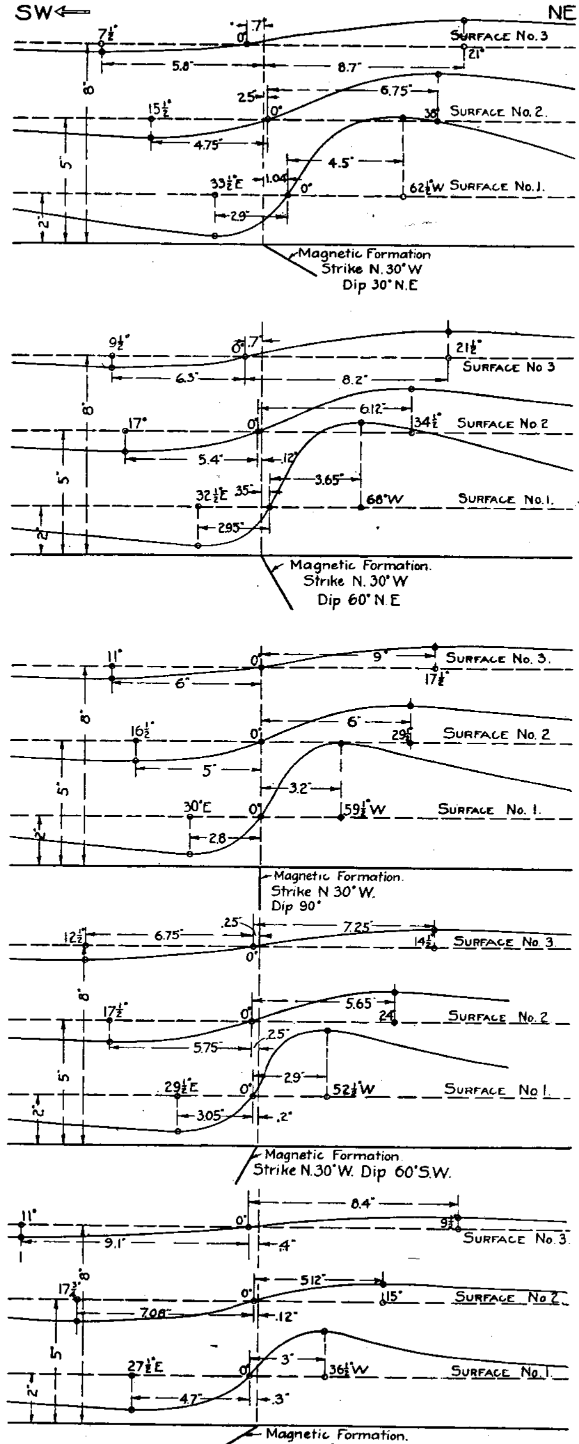

Fig. 24. Dial compass curves for strike N. 30°W. with various dips and depths of burial.

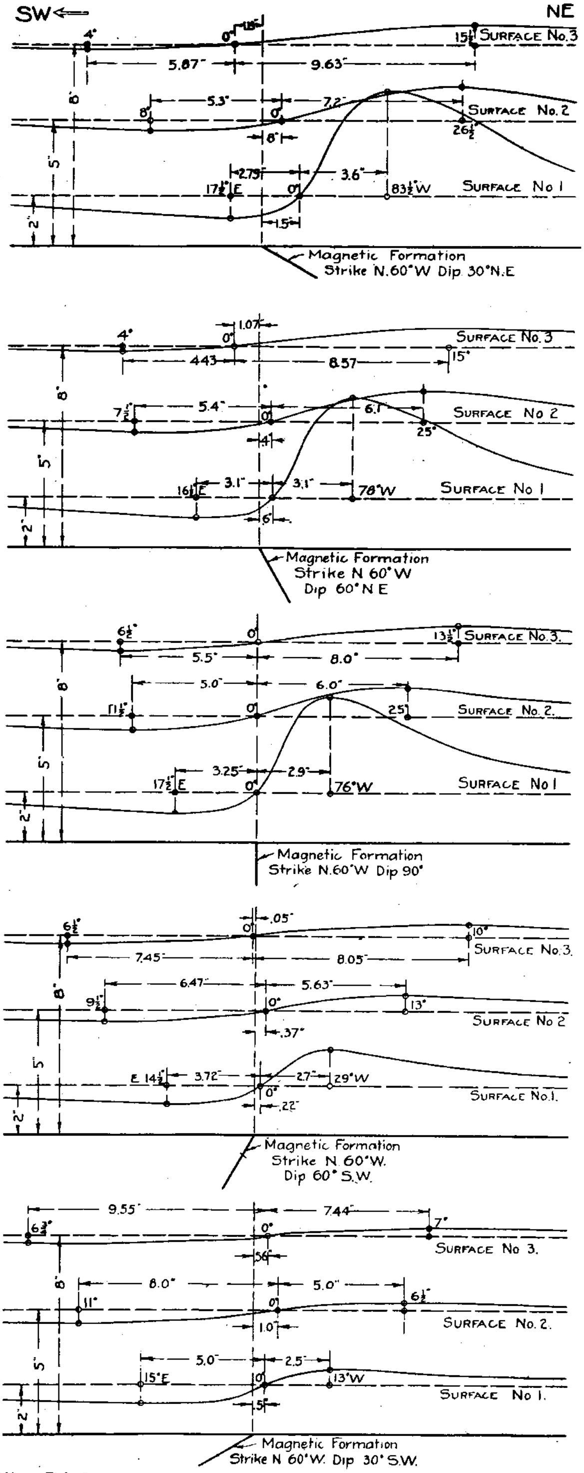

Fig. 25. Dial compass curves for strike N. 60° W. with various dips and depths of burial.

In order to check these experiments with a larger compass, and also for the purpose of getting the corresponding dip needle readings, another series of readings was made later, on an apparatus made by W. J. Mead for class demonstration. This apparatus

TABLE VI.

Dip	Dial Compass		Dip Needle			
	Ratio No. 1 Dist. of N. or E. M. / Dist. of S. or W. M.	Ratio No. 2 N. or E. M. / S. or W. M.	Maximum Reading	Direction of Maximum from Dial Zero	Location of steepest slope of curves from Dial Zero	Location of negative readings from Dial Zero
STRIKE NORTH-SOUTH						
30W°	.66	.62	42¾	W	W	4.8″ W
60W°	.91	.82	46½	O	E	6.9″ W
90°	1.09	1.00	45¼	O	W	7.4″ E & 7.2″W
60° E	1.08	1.13	36	O	W	5.0″ E
30° E	1.16	1.41	33¾	E	W	5.3″ E
STRIKE N. 30 W.						
30° SW	0.61	0.70	32	NE	NE	4.8″ W
60° SW	0.81	0.92	32	NE	None	7.4″E″&5.2″ W
90°	1.01	1.29	35½	NE	None	NE
60° NE	1.22	2.09	37½	NE	NE	4.4″ E
30° NE	1.51	2.50	36	NE	NE	4.2″ E
STRIKE N. 60 W.						
30° SW	0.50	0.33	38¾	SW	SW	5.1″ SW
60° SW	0.71	1.29	46¾	NE	SW	6.5″ SW
90°	0.86	1.72	50	-------------	SW	None
60° NE	0.74	1.50	53¾	NE	NE	4.9″ NE
30° NE	1.09	2.29	58¼	NE	NE	3.5″ NE
STRIKE E-W.						
30° S	1	1	31	-------------	S	5.3″ S
60° S	1	1	40½	-------------	N	5.9″ S
90°	1	1	44½		N	7.2″ S
60° N	1	1	47	-------------	S	4.7″ N
30° N	1.37	2.75	51¾	-------------	S	3.4″ N

was fitted with a holder for the dip needle, and the readings of both dip needle and dial compass were taken with the centers of the needles at exactly the same distance (6.4 inches) above the edge of the sheet of iron. Only one "depth" was taken for each position, instead of three as in the other experiment. Table VI gives the results of this experiment as shown graphically in figure 26. It also shows the relation of the shape and position of the dip needle curve to the dial compass curve.

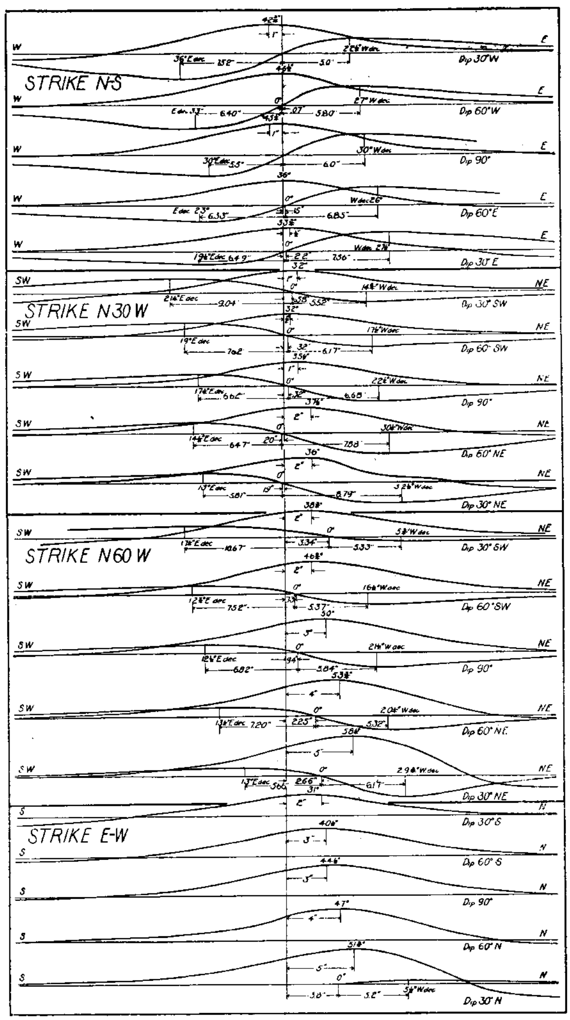

FIG. 26. Curves showing dial compass and dip needle readings for various positions of the iron sheet representing a magnetic formation.

From the plates and tables showing the results of these experiments the following generalizations appear for the particular apparatus used:

Strike N-S.—The dip of the beds is always toward the larger and more distant maximum. It is steep when maxima are nearly equal and at nearly equal distances from the zero point on the curve. It is gentle when differences between maxima are large and when the distances of the maxima from the zero point are markedly unequal.

When ratio No. 1 is less than .80 and ratio No. 2 is less than .70 the dip is about 30°W. Similar interesting generalizations appear for other dips of the formation.

Smyth states that the dip is "toward the nearer and (for north-south-striking rocks) the numerically smaller maximum." An inspection of the curves in figures 23 and 26 will show that in every case in the experiments made with a N-S strike it is the larger and more distant maximum that lies on the dip side. While the curve for the 90° dip indicates an unexpected lack of symmetry in the magnetic field, it does not seem that this is sufficient to cause the discrepancy between Smyth's mathematically derived conclusions and the experiments, for if it were, the curves for the dips to one side should agree with Smyth's statement, and curves for dips to the other side should be in marked disagreement. The curves show without exception, however, and in most cases quite strongly the correctness of the generalization that the dip is toward the greater and more distant maximum.

The dip needle curves of figure 26 and table VI give comparatively little information. The most typical point is that negative readings are found only on the side toward which the formation dips, at greater distances for steeper dips; and are found on both sides of the 90° dip. Another point is that the maximum reading is found on the dip side of the zero dial reading when the dip is 30°. The determination of the direction of dip of a formation by magnetic observations is an uncertain thing, and every other bit of evidence bearing on the question should be secured. In spite of its uncertainty, however, it is sometimes the only evidence to be had in many cases and so is worthy of careful study.

Strike N. 30°W.—For this strike the dial compass curves indicate that the dip is toward the more distant maximum, this rule failing to hold only for deeper buried beds dipping steeply S. W.

1. When ratio No. 1 is less than .90 and ratio No. 2 is less than 1.30 the dip is gentle and southward.

2. When ratio No. 1 is between .80 and 1.07 and ratio No. 2 is between .90 and 1.80 the dip is steeply southward.

3. When ratio No. 1 is between 1.00 and 1.40 and ratio No. 2 is between 1.30 and 2.25 the dip may be vertical or steeply to the northeast. The dip needle curves for these dips show very slight negative readings to the northeast for 90° dip and marked negative readings for the 60° N.E. dip.

4. When ratio No. 1 is greater than 1.40 and ratio No. 2 is 1.85 or greater the dip is gentle to the northeast.

5. Negative dip needle readings were almost invariably found on the dip side of the formation.

Strike N. 60° W.—For this strike the dial compass curves indicate that the dip is usually toward the more distant maximum. This rule holds most strongly where the dips are gentle.

1. When the dip is gentle and toward the southwest ratio No. 1 is between .50 and .75 and ratio No. 2 is between .33 and 1.00. The dip needle curve shows its steep part on the dip side.

2. When the dip is steeply southwest ratio No. 1 is between .75 and 1.15, and ratio No. 2 is between 1.29 and 2.00. The dip needle curve has the steep part on the dip side.

3. When the dip is 90° ratio No. 1 is between .86 and 1.45, and ratio No. 2 it between 1.70 and 2.17, except when the depth is slight, when it may exceed 4.00. The steep part of the dip needle curve is on the dip side.

4. When the dip is steeply northeast ratio No. 1 may be between .74 and 1.93, and ratio No. 2 varies from 1.50 to 4.00 and even greater for slight depth. The steep part of the dip needle curve is on the dip side.

5. When the strike is gentle and toward the northeast there is little to distinguish the readings from those for steep northeast dip. Ratio No. 1 tends to be a little higher but not enough to be definite. The dip needle curves show negative readings only on the dip side, and the steep part of the curve is also on the dip side.

Strike E-W.—The dial compass gives no indication of the dip of the rock for this strike. Table V shows values other than 1 for ratios No. 1 and No. 2 when the dip is gently to the north. This indicates that the iron sheet used was not truly east-west or that one part of it was different from the rest in magnetic properties. The dip needle curves show negative readings on the dip side, and on the south side for a dip of 90°.

General Conclusions.—The *character* of a magnetic rock can usually be told by the magnetic readings. Sedimentary rocks such as iron formation usually give more regular and more continuous belts of attraction than igneous rocks.

The *strike* of magnetic rocks is determined by connecting points of maximum dip needle readings, or zero points on the dial compass curves for successive traverses across the formation. The line drawn to connect these points is known as a "magnetic line."

The *dip* of magnetic rocks may oftentimes be determined from the magnetic readings. The experiments conducted and tests made in the field agree, and show in general that the dip is toward the greater and more distant maximum for all strikes when the dip is less than 60°. This conclusion disagrees with Smyth's paper, and it is regretted that time does not permit a careful study to determine the reason for this disagreement. It may be due to Smyth's incorrect assumption (page 314, loc cit.) that the magnetic force varies inversely as the square of the distance, or it may be due to the fact that the iron sheets used in the experiments were small in proportion to the distance between their poles and the compasses, when compared to a bed of magnetic rock and the distance of its poles from the compasses. At this point it is important to call attention again to the fact that the conclusions from these experiments apply only to the conditions of the experiment and need careful comparison with similar experiments made under known conditions in the field.

Negative dip needle readings are more likely to be found on the side toward which the rock dips according to the experiments, but too much dependence must not be placed upon this.

The *thickness* of a magnetic formation is always less than the distance between the maximum points on the dial compass curve.

The *width* of a magnetic curve—the distance across the strike through which abnormal attractions are found—depends upon the thickness and the depth of burial of the magnetic formation. A thin formation with a thin drift cover will give a narrow magnetic belt. With a thick cover the belt will be weaker and wider.

The *strength* of the local attractions depends upon the amount of magnetite in the formation and the depth of burial. Much magnetite means strong attractions, and little magnetite means weak attractions. A thin drift-cover means relatively stronger attractions than a thick cover.

Not all iron formations are magnetic, but most of them are. Magnetic lines of good characteristics are known to occur in the Lake Superior iron regions chiefly in areas of Huronian sediments or in greenstone beds associated with them. Hence, all such magnetic lines in this area are believed to indicate areas of Huronian rocks in which iron formations are likely to be found.

DETERMINATION OF THE DIRECTION AND INTENSITY OF THE MAGNETIC FIELD OVER MAGNETIC FORMATIONS

The direction assumed by the needle of the dial compass is the direction of the horizontal component of the magnetic field at that point of observation, but it gives no indication of what may be the actual direction of the magnetic pull. The position of the dip needle is due to the action of two pairs of forces acting to rotate it in opposite directions, as described on page 70, and consequently it also fails to give the actual angle of the earth's magnetic field. Neither instrument shows the actual strength—the intensity—of the magnetic attraction. As no observations on the actual direction and intensity of the earth's field in the neighborhood of magnetic formations were known it was decided to make a series in Florence County. Observations were first made at the southeast corner of section 20, T. 40, R. 18E. as this was at a distance from known local attraction and it was believed would give the normal for the district. Other determinations were then made as given in table VIII, page 104. The purpose in selecting these places was to secure data showing the effect of a magnetic formation on the actual direction and intensity of the earth's magnetic field. Wherever possible observation with the ordinary dip needle and dial compass were made in the same places for comparison.

The determinations made were (1) the intensity of the horizontal component, and (2) the inclination or dip of the field. From these two the total intensity was computed. By taking many observations of each factor at each station a very satisfactory degree of accuracy was attained.

Professor E. M. Terry of the Physics Department of the State University kindly consented to assist the writer in this, and the following discussion of the work is to be credited to him, excepting for locations and descriptions, and other minor data.

INSTRUMENTS USED AND PRINCIPLES INVOLVED

I. *The Magnetometer.*—The determination of H, the horizontal component of the earth's magnetic field was made by means of the magnetometer, i. e., a small magnet suspended by a silk fibre and free to oscillate through a small angle about its position of equilibrium. The period of such a magnet is given by the expression:

$$t = 2\pi \sqrt{\frac{I}{MH}} \qquad (1)$$

Where t = time of one complete vibration.
I = moment of inertia of magnet about the line of support.
M = magnetic moment of magnet.
H = intensity of the field in which it is vibrating.

If now, t_1 and t_2 are the periods in fields of intensities H_1 and H_2 respectively, we have:

$$t_1 = 2\pi \sqrt{\frac{I}{MH_1}}, \text{ and } t_2 = 2\pi \sqrt{\frac{I}{MH_2}} \qquad (2)$$

Dividing, we have:

$$\frac{H_1}{H_2} = \frac{t_2^2}{t_1^2}, \text{ or } H_1 = \frac{t_2^2}{t_1^2} H_2 \qquad (3)$$

If t_2 is determined for a known field H_2, H_1 may be computed by simply observing t_1. The measurement of H_2, the standard field, was made by means of the so-called "Absolute Magnetometer," and involves two determinations: (a) MH, and (b) $\frac{M}{H}$

(a) *The Determination of MH.*—As seen from equation (1) this is readily obtained by observing the period of the magnetometer when vibrating in the standard field, and determining I from the mass and dimensions of its magnet. Thus:

$$MH = \frac{4\pi^2 I}{t^2} \qquad (4)$$

$$\text{Where} \quad I = \left(\frac{l^2}{12} + \frac{r^2}{4}\right) m \qquad (5)$$

Where l = length of magnet
r = radius of magnet
m = mass of magnet.

(b) *The Determination of* $\frac{M}{H}$.—This is accomplished by observing the deflection of another much smaller magnet freely suspended in the standard field when acted upon by the magnetometer—magnet placed on its axis along the line of the perpendicular bisector of the small magnet; i. e., normal to the magnetic meridian, as shown in figure 27.

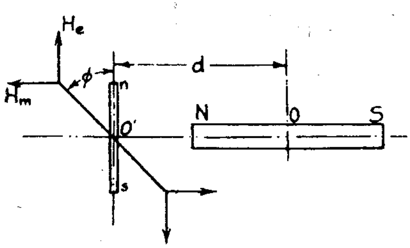

FIG. 27.

NS = magnetometer magnet
ns = small magnet
H_e = standard earth's field
H_m = field at O′ due to NS.

It is thus seen that while the earth's field tends to set *ns* normal to OO′, that of the magnetometer magnet tends to set it parallel to OO′. The equilibrium position, which is determined by the equality of the couples due to those two fields, is defined by the equation

(6) $$M'H_e \sin \phi = M'H_m \cos \phi$$

Where M′ = magnetic moment of ns.

(7) $$\text{Whence } \frac{H_m}{H_e} = \tan \phi$$

H_m is computed as follows, where *m* is the pole strength of *NS*.

$$\text{The field at O' due to N} = \frac{m}{\left(d - \frac{l}{2}\right)^2}$$

$$\text{The field at O' due to S} = \frac{-m}{\left(d + \frac{l}{2}\right)^2}$$

The total field at $O' = H_m$

$$= m\left\{\frac{1}{\left(d-\frac{l}{2}\right)^2} - \frac{1}{\left(d+\frac{l}{2}\right)^2}\right\}$$

$$= \frac{m}{d^2}\left\{\frac{1}{\left(1-\frac{l}{2d}\right)^2} - \frac{1}{\left(1+\frac{l}{2d}\right)^2}\right\}$$

$$= \frac{m}{d^2}\left\{1+\frac{l}{d}+\frac{3}{4}\frac{l^2}{d^2}+\ \ldots\ -\left(1-\frac{l}{d}+\frac{3}{4}\frac{l^2}{d^2}+\ \ldots\right)\right\}$$

$$= \frac{2ml}{d^3}$$

$$= \frac{2M}{d^3}$$

Substituting in (7)

$$\frac{2M}{d^3H_e} = \tan\ \phi$$

$$\text{or } \frac{M}{H_e} = \frac{d^3 \tan \phi}{2}$$

$$\text{Whence } H_e^2 = \frac{M\ H_e}{\frac{M}{H_e}} = \frac{4\pi^2 I}{t^2}\ \frac{2}{d^3 \tan \phi}$$

$$\text{or } H_e = \sqrt{\frac{8\pi^2 I}{t^2 d^3 \tan \phi}}$$

II. *The Dip Circle.*—The essential parts of this instrument are a slender magnetized needle about eight inches long, with pointed extremities, mounted on agate knife edges at the center of a graduated vertical circle which is placed in the magnetic meridian, the axis of rotation of the needle being normal to the plane of the circle. The circle is mounted so as to admit of rotation about a vertical axis, its position being indicated by a pointer and horizontal graduated circle. The supporting base has three legs provided with leveling screws, and a level is placed upon the frame carrying the vertical circle. If the instrument is mechanically perfect, when the plane of the vertical circle includes the magnetic meridian, the needle will indicate the direction of the resultant earth's field.

The principal sources of error in dip determinations arise from the following instrumental imperfections:

(a) The axis of motion of the needle may not pass through the center of the vertical circle.

(b) The center of mass of the needle may not coincide with its axis of motion as regards the length of the needle.

(c) The center of mass of the needle may not coincide with its axis of motion as regards the breadth of the needle.

(d) The magnetic axis of the needle may not coincide with its axis of figure.

(e) The vertical circle may not be properly set with reference to its axis of rotation; i. e., the line passing through the upper and lower 90° reading may not be vertical.

These errors may be eliminated in the following manner:

(a) By reading both ends of the needle.

(b) By reversing the polarity of the needle, thus causing the opposite end to dip.

(c and d) By turning the needle over in its bearings.

(e) By turning the circle through 180°, thus bringing the ends of the needle into different quadrants.

STANDARDIZATION OF INSTRUMENTS

I. *The Magnetometer.*—To standardize the magnetometer a point on the University Drive in Madison was selected at a long distance from railroad tracks, steel structures, etc., where the earth's field is very uniform. The period of vibration of the magnetometer, whose angular amplitude never exceeded 5°, was determined by a stop watch reading to fifth's of a second. This watch had previously been compared with the standard clock of the Washburn Observatory and found to have a rate of less than 1 part in 2000 which was deemed sufficiently accurate for the work in hand. The following are the times observed for twenty complete vibrations:

88.2 sec.
88.0
87.8
88.2 Period of one vibration $= t = \frac{88.12}{20} = 4.406$ sec.
88.4

Mean 88.12″

The constants of the magnetometer magnet are as follows:

	Diameter	Length	Mass
(Mean of 5 determinations)	—.3979cm	5. cm	4.734 grams.

$$\text{Moment of inertia} = \left(\frac{l^2}{12} + \frac{r^2}{4}\right) m$$

$$= \left(\frac{5^2}{12} + \frac{.1987^2}{4}\right) 4.734$$

$$= 9.910 \text{ gram cm}^2$$

Sustituting in equation (4), we have

$$MH = \frac{4\pi^2 I}{t^2} = \frac{4\pi^2 9.91}{4.406^2} = 20.18$$

For the determination of $\frac{M}{H}$ the absolute magnetometer belonging to the Electrical Laboratory of the Physics Department was used the angle ϕ (see figure 27) being measured by a telescope and scale, the distance between the scale and magnetometer mirror being 175.5 cm. Three determinations were made, using different values of *d*, placing *NS* on opposite sides of *ns*, and reversing between each setting. The results of these determinations, the value of $\frac{M}{H}$ and the value of H are given in table VII, in which D is the observed deflection of the beam of light on the scale.

TABLE VII

Calculation of $\frac{M}{H} = \frac{d^3}{2} \tan \phi$.

	d	D	tan 2 φ*	2φ	φ	tanφ	d_3	$\frac{M}{H}$
I	38.1	7.76	.0448	2° 34.′	1° 17′	.0224	55300	619.
II	33.1	11.93	.0687	3° 54.5′	1° 57.3′	.0341	36270	617.5
III	28.1	19.55	.1126	6° 21′	3° 10.5′	.0557	22190	617.
							Mean	618.

$$H^2 = \frac{MH}{\frac{M}{H}} = \frac{20.18}{618} = .03265$$

H = .1808 gauss**

II. *The Dip Circle.*—The only standardization for the dip circle, aside from making the needle as nearly balanced mechanically as possible and polishing the bearings, is to secure parallelism between the level and the supporting frame of the vertical circle. This was accomplished in the usual manner of adjusting a level bubble.

The determination of the dip in the standard field was as follows:

	A Dipping			B Dipping		
	U	L	Mean	U	L	Mean
EF	77	76.6	76.8	74.4	74.3	74.35
WF	72.8	73.	72.9	77.9	77.8	77.85
WB	80.	80.	80.	74.7	74.9	74.8
EB	74.6	74.4	74.5	77.1	76.6	76.85
		Mean	76.05		Mean	75.96

Dip = 76.005°

The above letters have the following meanings:

A, B = labels on ends of needle.

U, L = reading of upper and lower ends of needle on vertical circle.

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* The reflected beam is turned through twice the angle of rotation of the mirror.

** The gauss is the unit of field strength. It is defined as a field which acts on a unit pole with unit force (1 dyne).

EF = Vertical circle turned to read from the east and lettered side of needle facing graduated side of circle.

WF = vertical circle turned to read from the west and lettered side of needle facing graduated side of circle.

WB = vertical circle turned to read from the west and back of needle facing graduated side of circle.

EB = vertical circle turned to read from the east and back of needle facing graduated side of circle.

The dip circle readings were always taken in the above order, and this nomenclature will be followed throughout.

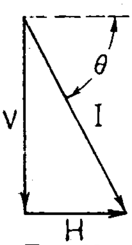


FIG. 28.

Calling H = Horizontal intensity of Earth's Field
V = Vertical Intensity of Earth's Field
I = Total Intensity of Earth's Field
θ = Angle of Dip

We have $V = H \tan \theta$

$$I = \frac{H}{\cos \theta}$$

The constants of the standard field are then as follows:

$$H = .1808$$
$$V = .1808 \times 4.012 = .7228$$
$$I = \frac{.1808}{.2419} = .7475$$
$$\theta = 76.006°$$

METHOD OF TAKING OBSERVATIONS

The routine followed in making a determination was as follows: a Johnson plane table, the large table of which was replaced by a smaller one 12x12x2 inches, was set up at the desired position, made approximately horizontal by means of a small pocket level, and clamped. The table was then rotated until one of its edges was parallel to the magnetic meridian, as indicated by a sensitive compass. The dip circle was then placed upon it and set so that the pointer on the horizontal circle read zero, when the base was turned until the plane of the circle was parallel to the edge of the table. The circle was then carefully levelled by means of the levelling screws. The needle was then magnetized and the observations taken as indicated on page 99, A dipping; after which it was removed and its magnetism reversed by stroking with a strong bar magnet, when the same readings were taken with B dipping. The dip circle was then replaced by the magnetometer, and the time of 20 complete vibrations measured several times by the stop watch.

RESULTS

In order to test the accuracy with which observations could be repeated, and to gain an idea of the undisturbed field in the locality of Florence, a few determinations were made about half a mile west of the village, at a considerable distance from railroad tracks and ore deposits. Station No. 1 was at the southwest corner of section 20, T. 40—R. 18E. in the middle of the road. Stations No. 2, No. 3 and No. 4 were in the road, respectively 100, 200 and 300 feet west of Station No. 1. Determinations were then made in an area of general high attractions on the Commonwealth lands. The place chosen was about 40 paces west of the old field, near the west side of section 34, and the stations were north of the main road to the Buckeye mine. Station No. 1 was 20 paces north of the road, No. 2 was 100 feet north of No. 1, No. 3 was 200 feet north of No. 1.

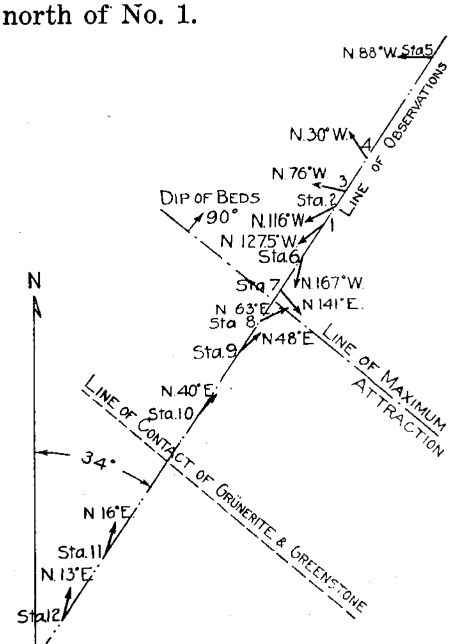


FIG. 29. Magnetic observation stations on Dunkles farm. Arrows give dial compass directions.

The day following the making of these determinations was rainy, so it was decided to take some observations underground in the Florence mine. The observations were made in abandoned workings as far as possible from tracks and electric wires. Station No. 1 was on the 5th level and No. 2 was on the 3rd level near the hanging wall in number 8 crosscut, 20 feet north of the east drift.

The main series of determinations was made across the magnetic line of Dunkle's farm. The location of the various stations and the declination of the horizontal needle at each station are shown in figure 29. The position of Station No. 1 on this line is about 50 feet north of the pit in grunerite schist, 85 paces west and 740 paces south of the ⅛ corner between the N. E. corner and the N¼ stake of section 35, T. 40—R. 17E. The line on which the observations were made was approximately at right angles to the strike of the magnetic bed. The drift cover over the magnetic rock was about five feet, as near as could be estimated. The greenstone southwest was outcropping. The results of these observations are all given in Table VIII.

TABLE VIII

Location	Station No.	Period of Vibration	H	Dip	V	I	Dip Needle	Dial Compass
S. E. cor. of Sec. 20, T. 40, 18 E.	1	4.85	.1493	75.89	.5945	.6128	0°	----------
	2	4.85	.1493	75.88	.5945	.6128	0°	----------
	3	4.857	.1488	75.90	.5924	.6108	0°	----------
	4	4.863	.1484	75.85	.5885	.6030	0°	----------
West line of Sec. 34 T. 40, 18E.	1	4.79	.1530	76.22	.6235	.6410	7.5°	----------
	2	4.807	.1518	76.00	.6094	.6280	7.5°	----------
	3	4.806	.1520	76.27	.6255	.6437	8.°	----------
Florence Mine	1	4.82	.1511	75.67	.5910	.6108	----------	----------
	2	4.76	.1550	75.96	.6185	.6400	----------	----------
Dunkle's Farm	1	5.375	.1215	81.67	.8432	.8508	49°	128° W
	2	6.155	.09285	82.89	.7445	.7500	47°	116° W
	3	7.67	.05970	84.73	.6480	.6520	49°	76° W
	4	7.62	.06046	84.59	.6385	.6405	52°	30° W
	5	4.485	.1745	76.15	.7078	.7292	18°	88° W
	6	5.315	.1242	83.22	1.002	1.052	63°	168° W
	7	4.480	.1748	82.96	1.327	1.337	66°	153° E
	8	3.150	.3538	71.46	1.0560	1.1130	41°	63° E
	9	3.026	.3835	65.67	.8480	.9312	22°	48° E
	10	3.184	.3466	67.59	.8400	.9090	7°	40° E
	11	4.145	.2042	71.25	.6020	.6360	0°	16° E
	12	4.273	.1922	72.43	.6073	.6373	-1°	13° E

The "dip needle" column gives the variation from normal of an ordinarily dip needle balanced so its normal reading was + 12°. The "dial compass" column gives the declination of the horizontal needle from its normal position 2¾° east of north.

The variations of the magnetic elements and the behavior of the counterpoised dip needle—the kind ordinarily used in the Lake Superior iron districts—in crossing a magnetic formation may be seen from figure 30, where the observations taken on Dunkle's farm have been platted. Perhaps the most striking feature of these curves is the tendency of the counterpoised dip needle to follow the variations in both the intensity and the dip of the earth's

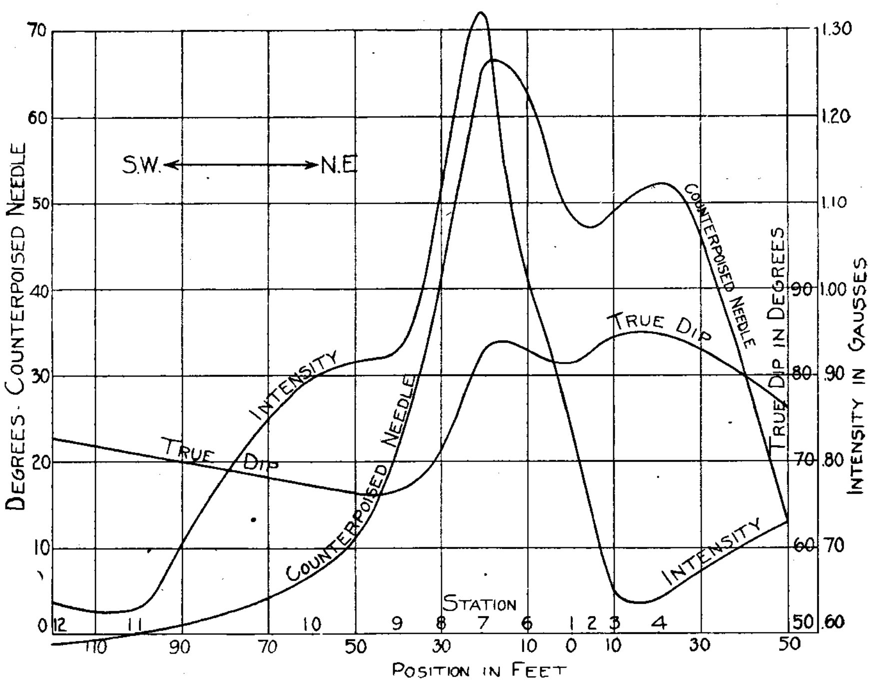
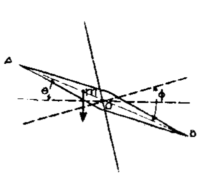


FIG. 30. Curves showing magnetic observations on Dunkle's farm west of Florence.

field. That it should behave in this manner may be seen from the following considerations: Let *I*, the long arrow in figure 31, represent the direction and magnitude of the earth's field, and let *AB* be the position of the needle which is mounted at O, with its center of mass at *m*. The condition for equilibrium is given by $k \cos \theta = I\, M \cos \varnothing$.



M = magnetic moment of needle.
θ = indicated dip.
$\varnothing$ = angle between axis of needle and the normal to I.
k = a constant depending upon mass of needle, distance of center of mass from axis of rotation, etc.

FIG. 31.

The right hand member of this equation represents the couple tending to produce a rotation in the clockwise direction, i. e., to increase the reading of the instrument, while the left hand member represents the couple tending to decrease it. It is thus evident that a change in either the magnitude or the direction of I will affect the indication of the instrument, but that the change of readings is in no wise proportional to the change in I, since the restoring couple is proportional to $cos\theta$ instead of θ. Thus, if θ is large, $cos\theta$ is small, and changes rapidly with θ. In this position, a small change in the direction of I will produce a large change in θ, but in this position the instrument is relatively insensitive to changes in the magnitude of I, since the angle between I and the axis of the needle is small. This fact is illustrated by the observations at stations 4 to 7 on the plat, where it is seen that the changes in true dip are magnified in the curve for the counterpoised needle, while it has not as sharp a maximum as the intensity curve, showing the decrease in sensibility to this factor.

On the other hand, when θ is small, the restoring couple is large, thus reducing the sensitivity to changes in both the magnitude and direction of I; but on account of the decrease in ϕ in this position, the sensitivity to changes in magnitude of I is relatively increased. Thus, at stations 9 to 12, although the true dip is increasing, the rapid decrease in intensity reduces the readings of the counterpoised needle to very small and even negative values. Because of the dependence of the counterpoised dip needle upon these two factors, and of the varying effectiveness of each with position, the impossibility of separating them is apparent. Hence, the instrument cannot be used for quantitative determinations; but as a qualitative instrument for locating magnetic disturbances it is very sensitive, and has a large field of usefulness.

CHAPTER V

LAND CLASSIFICATION

LAND CLASSIFICATION NECESSARILY A PUBLIC FUNCTION

The people of the state of Wisconsin are interested in and benefited by the development of all parts of the state to the fullest possible extent. The building up of the manufacturing industries of any section brings a new element of prosperity not only to the people of that particular locality but to many people in other localities and in apparently unrelated lines of endeavor. The agricultural development of northern Wisconsin is not only of benefit to the farmers who profit by their labors and the rise in land values, but it also makes more business for the cities both of the immediate region and at long distances from it. The prosperity of these cities makes better markets and greater prosperity for the farms surrounding them. It is thus easy to see how the farmer clearing land in northern Wisconsin is of direct benefit to a farmer in Milwaukee, Dane or Rock county. The benefit may be small in an individual case but is large in the aggregate. The full development of any natural resource likewise reflects its benefits over a wide territory. The cases are rare where an individual can prosper greatly without directly or indirectly increasing the prosperity of many of his associates and the community in which he lives.

Notwithstanding the evidently good public policy of promoting the development of an iron mining industry in northern Wisconsin the question is sometimes asked "why should the state do this —why should it not be left to the individual initiative of those interested." The direct answer is that the people collectively, through the state government, can at slight expense do what the individual land owners would find prohibitively expensive. On this same principle the state maintains an agricultural department to carry on beneficial investigations that individual farmers could not afford, a factory inspection system to do for the good of the individual working man what he could not do for himself, and many similar activities. As a matter of fact the basic principle of all governmental activity is for the people as a group to do certain things that they can do more cheaply and more effectively than as individuals.

The indirect answer to the question is that it is beyond the bounds of practical possibility to get the land holders to unite to carry on such work. There is an area of about 360 square miles in northern Wisconsin, not included in this report, where the indications would warrant the private owners in paying for such a survey. In 1911 the ownership was concentrated in few hands, and to these owners the proposition was made that this Survey would take active charge of the work and furnish expert supervision without charge provided it was given the right to publish the results. Many of the owners were willing to pay their share but it was found impossible to get them all together.

In a hearing before the Finance Committee of the House of Representatives at Washington, Representative Sherley made the statement that "so far as the development of the mineral resources of the country is concerned, it is just as important to know the resources of privately owned lands as of government owned lands."* The state of Wisconsin is not particularly interested in discovering the fact that on a particular 40-acre tract of land belonging to George Smith there may be iron ore, but it *is* very much interested in the fact that in that region there is the possibility of developing a mining industry that will add millions of dollars to the wealth of its citizens. It was for this purpose that the surveys made for this report were directed to be made by the legislature and the necessary money appropriated.

PURPOSES OF LAND CLASSIFICATION

"Utilization of lands for their greatest value necessitates the determination of that value (or those values, W. O. H.), which is, briefly, land classification; and, to be adequate, land classification must be based on first hand acquaintance with the land under consideration."** In northern Wisconsin the greatest value of the lands is usually the agricultural value. Other values sometimes so greatly exceed this as to become the paramount consideration. These other values consist chiefly of timber, water power

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* Thirty-fifth Annual Report of the director of the U. S. Geological Survey, p. 10.

** The classification of the Public Lands. George Otis Smith and others. Bull. 537, U. S. G. S., p. 7.

possibilities, and mineral rights. The timber values very often are exclusive of agricultural values; that is, certain lands are of so little agricultural value that their value for forestry purposes exceeds any probable value for agricultural purposes. Such values are determinable only by a careful classification on the basis of soil conditions—a soil survey—such as this Survey is now conducting over the whole state.

The water power values are exclusive of other values. Use of land for water storage destroys the value for agricultural and mineral development. Such values can be obtained only through a classification of the lands by a survey of the power possibilities, such as this Survey carried on for a number of years, and is now being carried on by the state Railroad Rate Commission in cooperation with the United States Geological Survey.

The mineral values are not exclusive of the agricultural values but are additional to them. Land may be of value for both purposes and used for both purposes. Indications of the presence of iron ore, upon which mineral values depend, can be determined by a geologic and magnetic survey such as forms the basis of this report, and a survey of this kind is necessary for the intelligent classification of mineral lands.

Recognition of the existence of possible mineral value in the lands of northern Wisconsin has been a matter of common business for many years. It is probable that most transfers of large land holdings made in the last ten or fifteen years have conveyed title to the agricultural and timber values only. Many pieces of land sold to settlers have been transferred subject to the reservation of the mineral rights. Concerning the actual presence of mineral values nothing has been known in detail, but there has been sufficient general knowledge to warrant following this procedure as a practical business policy.

A classification of the lands of northern Wisconsin on the basis of mineral value should therefore have for its purpose two things; first an expression of all the positive determinations that can be made of the presence or absence of such values; and second, grading according to the evidence available all lands for which positive determinations are impossible. If the geology of certain lands is such that there is no possibility of iron ore being found this should be ascertained and made known. If certain other lands are known to be underlain by iron-bearing formations this positive determination should be made and published.

It is always the case in the examination of lands for such a classification that these positive determinations can be made only in certain favorable areas where the evidence is unusually good. Much of the area examined will be so completely covered by soil or other mantle rock that the evidence obtainable will be what a lawyer might call "circumstantial" and will only indicate possibilities or probabilities without furnishing the definite proof necessary for a positive determination.

An adequate scheme of classification must therefore contain not only provisions for positively definable classes but must provide classes graded according to the strength or weakness of the indications found. These classes must be understood to be subject to revision as rapidly as the discovery of new evidence permits positive determination. This new evidence for the area considered in this report must come largely from reports of exploration work and from information obtained from wells. If persons drilling wells to rock will send samples of the rock found to this Survey it will be of great assistance in more definitely classifying the lands, and the courtesy will be appreciated highly.

PRINCIPLES OF IRON LAND CLASSIFICATION

The iron-bearing formations of the Lake Superior region occur only in pre-Cambrian rocks. The iron producing formations are localized in belts of limited extent. Their locations and extent are shown in a general way in figure 1, page 3. It will be noted, on reference to this figure, that these productive ranges lie in the great area of pre-Cambrian rocks stretching from Wisconsin Rapids, northward beyond Lake Superior, covering most of northern Michigan and Minnesota and extending across northern Wisconsin. It will also be noted that there is a general trend of these ranges in a direction somewhat north of east. As this general trend of the pre-Cambrian formations is known to be continuous across northern Wisconsin the expectation is warranted that somewhere, concealed beneath the thick glacial drift, the iron-bearing formations are present in this state, as well as in those regions of Michigan and Minnesota where the rocks are better exposed. This fact of identity of geologic age and structure is the general principle on which to base the classification of northern Wisconsin as possibly iron-bearing.

The problem is then presented to limit these general possibilities to as closely prescribed areas as the information obtainable will permit. This is accomplished by two methods; first, a careful study of all rock exposures, and securing all the information that these may offer, and second, a careful magnetic survey to secure all the information that the magnetism of the rocks may give.

It must be borne in mind constantly that the point of view in this report in interpreting the information obtained in these ways for the purpose of eliminating lands must be radically different from that of the successful explorer. The explorer is justified in condemning for his purposes, which are immediate, all lands that do not at present offer strong encouragement of a successful outcome to his work. The point of view of this report must be to consider that all lands offer some possibilities for the discovery of ore, unless they are definitely known to be underlain by rocks in which ores cannot occur. The explorer demands definite information, which in many cases is not available, and the geologist must recognize that, while this information is not now available, it may become so in the future.

With regard to the value of a magnetic survey for the purposes outlined the following statement will be of interest.

"All ores of iron are found to be magnetic when tested by sufficiently delicate means. Ordinarily magnetite is the only iron mineral which causes conspicuous disturbance of the magnetic needle. Practically all the Lake Superior iron-bearing formations contain at least minute quantities of magnetite, and hence all exert an influence on the magnetic needle, but in widely varying degree. The iron-bearing formation of the Vermilion district and other Keewatin areas is strongly magnetic. The same is true of the formation in the east end of the Mesabi district, the Gunflint district, the Cuyuna district, and the east and west ends of the Gogebic district, and of most of the Negaunee formation of the Marquette district. Less magnetic parts of the iron-bearing formations are those producing principally hematite and limonite, as the central and western parts of the Mesabi, the central part of the Gogebic, and parts of the Menominee and Crystal Falls districts. The iron-bearing member of the Iron River district of Michigan affects the magnetic needle only locally and slightly.

"Every known iron-bearing formation in the Lake Superior region, with the exception of that in part of the extreme west end of the Mesabi district, has been outlined partly as a result of magnetic surveys. In some of the districts, as, for instance, the Iron River district, the magnetic variation is slight, but careful observations will detect it. In addition several magnetic belts are known in which exploration has not yet shown the character of the iron-bearing formation."*

The principles of classification of iron bearing lands have been worked out as the result of many years of careful, detailed geologic and magnetic surveys of the productive iron ranges of the Lake Superior region by the U. S. Geological Survey, the various state geological surveys and the large mining companies which have maintained staffs of geologists. They have been, and are, in constant successful application, both by public and private surveys, and there is no new principle involved in the work done for this report. The only difference from established usage is that heretofore the private surveys have usually been the ones that have gone into new or previously unproductive territory, and the official surveys have, in general, followed the first discoveries of ore.

SYSTEM OF CLASSIFICATION ADOPTED

The classification adopted for the lands covered in this report has the purpose stated and is based on the principles outlined above.

The lands are divided into five classes. Two of these classes include the lands for which reasonably definite classification is possible. Those known to contain iron formation are the "Class A" lands. Those known to be underlain by rocks in which ore is not found are the "Class D" lands. The other three classes include those for the definite classification of which sufficient evidence is not available at present. These are classified according to the character and amount of evidence pointing toward the presence or absence of iron formation.

Classes *A* and *B*, and the most favorably situated of Class C, are recommended for more detailed examination. It is believed that a detailed examination will show that a fair percentage of this land is worthy of exploration by drilling.

In the township descriptions are paragraphs giving recommendations for or against the advisability of exploring in each township, and pointing out in detail the most favorable locations for exploration if any work is to be done.

The details of evidence to be looked for to determine the class in which particular parcels of land should be placed are as follows:

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* **The Geology of the Lake Superior Region, C. R. Van Hise and C. K. Leith. Mon. LII. U. S. G. S., p. 486.**

Class A Lands.—This class includes all land in which iron formation is known to be present. This may be shown either by one or more of the following lines of evidence.

1. Outcrops of iron formation. No attempt has been made to subdivide this class into lands containing rich or poor iron formation.
2. Crossed by magnetic lines traced from outcrops of iron formation found elsewhere.
3. Exploration records, either drill holes or test-pits, which show the presence of iron formation.
4. Contiguity or relation to known iron formation, such as the presence in an adjoining section of a belt of iron formation striking toward the land in question, with some other evidence that the same strike continues.

Class B Lands.—This class includes all lands which show strong but not positive evidence of the presence of iron formation. This may be shown by any one of the following lines of evidence. (Some of these lands are possibly better to explore than some in Class A).

1. Abundant angular pieces of iron formation with or without a magnetic line.
2. A moderate amount of angular iron formation drift with a magnetic line of good characteristics see page 54).
3. Magnetic line of good characteristics in slates or other Huronian sediments. Since the iron formations are almost always associated with slates, the presence of a good magnetic line in rocks of this character is strong evidence of the presence of iron formation.
4. Geological relations showing a succession of formations which elsewhere contain an iron formation but for which no local evidence—such as drift or a magnetic line—can be found.

Class C1 Lands.—The Class C lands are those concerning which little information is available. They are divided into two classes on the basis of magnetic lines, and the geologist's best judgment as to whether or not they are underlain by Huronian formations in which an iron formation may occur. The Class C1 lands are those *probably* underlain by Huronian rocks and crossed by magnetic lines showing good characteristics. Some of these lands with the best magnetic indications may be better to explore than some in Class B.

Class C2 Lands.—These include lands which may *possibly* be underlain by Huronian rocks, have irregular magnetic lines or none at all, and no other indications of the presence of iron formation. For the classification of these lands there is very little or no information available. They may be underlain by igneous rocks, and many sections in this class undoubtedly are, but there are no outcrops or other data showing this. Because of the lack of evidence they are not recommended for exploration, but this fact must not be interpreted as meaning that there is no chance for the finding of iron ore in this class of lands. The prudent man will not spend much money in exploring them, neither will he condemn them absolutely.

Class D Lands.—This class includes all lands known to be underlain by rocks in which iron ore does not occur in the Lake Superior region. Thus lands underlain by granites, gneisses, schists, Keweenawan traps and sediments, Huronian quartzite, rhyolites and syenites are as a rule put in this class. Greenstones may be closely associated with iron formation so the lands underlain by them cannot be safely put in this class. Another exception must be made in the case of the Barron quartzite which is believed to be only a thin cover over the older rocks in much of the area where it is found. The land where this is true must usually be placed in one of the C classes.

It is obvious that the foregoing classification must be arbitrary in many cases. In fact it is unusual that there are instances where the evidence is so complete that there is no room for honest difference of opinion. The experience of the U. S. Geological Survey in classifying the lands of the public domain in the western states agrees with our own.

"In preparing the regulations for classification three principles are paramount: (1) The regulations must be based on demonstrated facts or on well-founded and generally accepted inferences; (2) they must be based on all stable, permanent factors involved; (3) they must be as definite yet withal as simple as possible. Ideally the regulations should be so simple that anyone at all acquainted with the subject could correctly apply them, and they should be so definite as to admit of little or no disagreement in interpretation. Neither of these ideal requirements can be realized."*

* Classification of the Public Lands Loc. cit., p. 66.

CHAPTER VI

RESULTS OF EXPLORATION BY DRILLING

Drilling operations along lines of magnetic attraction have exposed locally the character of the country rock, and in many instances their relationships and structure. Insofar as the magnetic line or zone probably represents the extent of at least one rock formation, the results of drilling not only serve in the identification of that formation and its relations to adjacent rocks, at least locally, but thereby enable the projection of these rocks on the map within reasonable limits into the surrounding area. It does not follow that from the information gleaned from a few holes drilled for a definite and specific purpose that generalized mapping of extensive areas is warranted, nor that formations other than those drilled do not exist in the adjacent areas. The information is both meager and lacking in quantitative features. However, to a certain extent this sort of information proves the presence or absence of iron formation in the location drilled, and since magnetic attraction is one essential property of iron formation it is along the magnetic lines that there is the greatest likelihood of iron formation within the area. Therefore, the presentation in this place of the geological data derived from drilling is of value in reference to iron ore possibilities and as a source of purely geological information.

These results have been obtained through the courtesy of the exploration companies and have been presented in summary form. Drilling was done both previous to and following the publication of Bulletin XLIV of this survey. All holes are vertical. Core in many cases has been examined in the Survey offices and unless otherwise stated the determinations are from the Survey records. Thin section descriptions were made by the Survey. The order in which results are reported by townships begins at the southernmost and proceeds from east to west.

TOWNSHIP 33N.—RANGE 8W.

This drilling was done in 1917 by the Loretta Mining Company under the direction of H. I. Pearl. Fig. 32 shows the location of the holes in relation to the magnetic lines which prompted the exploration.

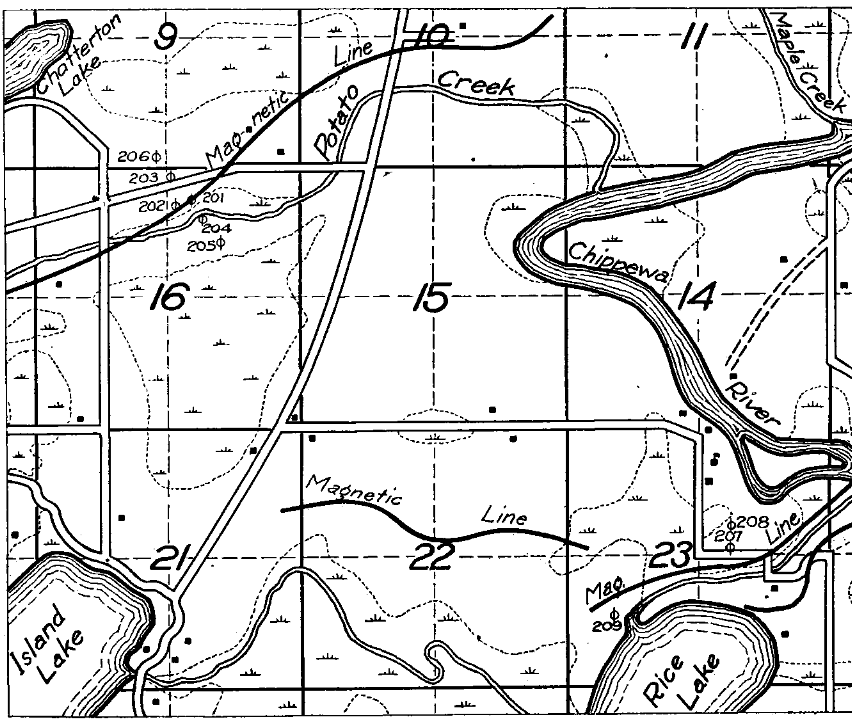


FIG. 32. Location of drill holes T. 33N., R. 8W.

THE NORTH MAGNETIC LINE

Hole No. 201. No data.

Hole No. 202.

0–157′	Surface material.
157–165′	Dark gray, porphyritic rhyolite with abundant fine grained magnetite. Rough banding steeply inclined to the surface.

Hole No. 203.

0–170′	Surface material.
170–175′	Dark gray rhyolite without doubt from the same formation as that encountered at 157′ in hole No. 202.

Hole No. 204.

0–171′ Surface material.

171–185′ Gneissic pink rhyolite with original porphyritic texture.

Hole No. 205.

0–143′ Surface material.

143–155′ Finely banded dark gray to black, fine grained porphyritic rhyolite. Under the microscope the thin section shows a ground mass which is cloudy with viriditic material but the fine grained siliceous composition can be readily seen. The green material occurs chiefly in certain streaks which give a banded appearance to the rock. Magnetite is abundant especially in these darker bands. The "eyes" or phenocrysts are for most part shadowy areas composed of feldspar, but which have been altered to carbonate and epidote. Green biotite forms large flakes. The siliceous composition, the fine quartz-feldspar ground mass, with feldspar phenocrysts, the banding which is believed to be original flow structure are points believed to indicate the effusive igneous character of this rock.

Hole No. 206.

0–143′ Surface material.

143–195′ Roughly banded dark gray rhyolite very likely the same as that from holes No. 202 and 203.

THE SOUTH MAGNETIC LINE

Hole No. 207.

No core was examined in the Survey office. The hole was ledged in granite at a depth of 110 feet.

Hole No. 208.

0– 99′ Surface material.

99–110′ Disintegrated pink granite.

Hole No. 209.

No core was examined in the Survey office. The hole was ledged in granite at a depth of 104 feet.

Summary.—Drilling in this township along two magnetic lines shows that the attraction is caused by igneous rocks. The identity of the magnetic formation in the north line has been established in a series of steeply dipping magnetic rhyolites found in holes 202, 203 and 206 north of that line and 205 on the south. The porphyritic pink rhyolite in hole 204 is probably a phase of the same rock. Magnetite somewhat concentrated along lines which probably represent original flow structures cause the attraction which has been traced as the magnetic line.

While fewer holes were drilled on the south line, and only disintegrated material unsatisfactory for examination was available in the Survey office the attraction is clearly due to igneous rocks although identity of the magnetic formation was not established.

TOWNSHIP 36N.—RANGE 8W.

This drilling was done in 1917 under the direction of O. W. Wheelwright. The location of the holes and the magnetic line which was explored is shown in figure 33.

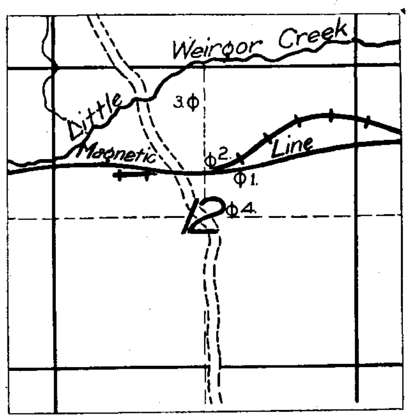


FIG. 33. Locations of drill holes T. 36N., R. 8W.

Hole No. 1.

0–124′	Surface material.
124–140′	Barron quartzite.
140–202′	Magnetic red schist grading into green schist similar in character to that outcropping in section 10.

Hole No. 2.

0–120′	Surface material.
120–141′	Barron quartzite.
141–142′	Red rhyolite porphyry.

Hole No. 3.

0–178′	Surface material.
178–198′	Pink granite gneiss.

Hole No. 4.

0–130′	Surface material.
130–203′	Barron quartzite.
203–215′	Diorite. Core not examined by Survey.

Summary.—The magnetic line is probably due to the green schist.

TOWNSHIP 36N.—RANGE 9W.

This drilling was done in 1913–14 by the M. A. Hanna Company under H. I. Pearl and none of the core was examined by the Survey. Location of holes is given in figure 34.

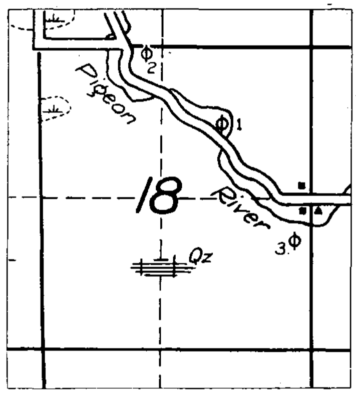


FIG. 34. Location of drill holes T. 36N., R. 9W.

Hole No. 1.

0–115′	Surface material.
115–117′	Sandstone (Cambrian).

Hole No. 2.

0– 78′	Surface material.
78– 80′	Quartzite (Barron).

Hole No. 3.

0–120′	Surface material.
120–130′	Sandstone (Cambrian).

Summary.—The data from these holes indicate that the history of the Valley of Pigeon River is as follows:

1. Erosion of the valley probably in post-Keweenawan time, since the Barron quartzite has been considered as of Keweenawan age.
2. At least partial filling of this valley with sandstone in Cambrian time.
3. Post-Cambrian erosion of the valley.
4. Glaciation and post-glacial erosion.

The drilling gives no clue to the character of the rocks underlying the Barron quartzite.

TOWNSHIP 37N.—RANGE 2E.

This drilling was done in 1916 by the Crosby Exploration Co., under the direction of C. A. Cheney. The core was not examined in the Survey office. For location of holes, see figure 35. All holes were ledged in magnetitic hornblende schist.

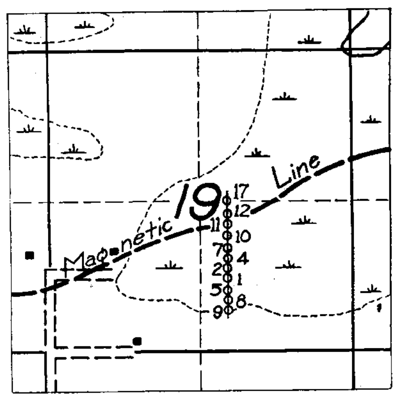


FIG. 35. Location at drill holes T. 37N., R. 2E.

Hole No.	Depth of Surface Material	Total Depth
17	20	20
12	84	86
11	78	79
10	76	79
7	55	62
4	50	60
2	49	64
1	50	55
5	53	60
8	110	111
9	75	76

TOWNSHIP 37N.—RANGE 6W.

This drilling was done in 1917 by the American Immigration Company, Figure 36 gives the location of the holes.

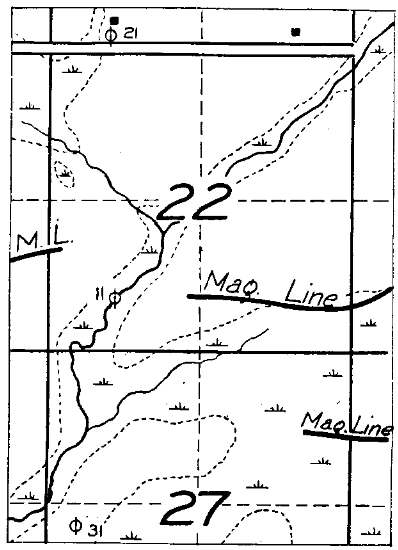


FIG. 36. Location of drill holes T. 37N., R. 6W.

Hole No. 11.

0– 26′ Surface material.

26– 39′ Dense green serpentine rock. Core sample is strongly magnetic and shows polarity. The thin section is composed essentially of serpentine which is crossed by streaks of magnetite which cut at angles close to 90 degrees. Within the rhombic areas thus formed irregular dissemination of magnetite occurs in fine specks as well as large rhombs. Sericite is also present in considerable quantity. The origin of the rock is not apparent and may have been a magnesian sediment.

Hole No. 21.

0– 44′ Surface material.

44– 59′ Pink gneissic granite.

Hole No. 31.

0– 95′ Surface material.

95–105′ Finely laminated schist composed of quartz, feldspar muscovite and biotite. Magnetite and pyrite are present. The sedimentary origin is not precluded by any data at hand but the summary evidence is best indicative of a derivation from a fine grained granite. The structure in the core shows a dip of about 70°

Summary.—This drilling furnishes but little information regarding the cause of either of the magnetic lines because hole No. 11, from which the only magnetic material was obtained is located in a position which is not clearly related to a definite magnetic line. It is clear that the area is, on the whole, within the granite area.

TOWNSHIP 37N.—RANGE 9W.

This drilling was done in 1913–1914 by the M. A. Hanna Company under H. I. Pearl. The core was not examined by the Survey. Location: 1025′ west, 100′ north of the SE corner of Section 1.

Hole No. 201.

0–68′	Surface material.
68–71′	Quartzite (Barron).

Summary.—The location lies within the area mapped as Barron quartzite, and the drilling provides no additional data concerning the rocks underlying that formation.

TOWNSHIP 38N.—RANGE 2E.

This drilling was done in 1916 by the Crosby Exploration Co., under the direction of C. A. Cheney. The core was not examined in the Survey office. See figure 37 for location of holes. All holes were ledged in magnetitic hornblende schist.

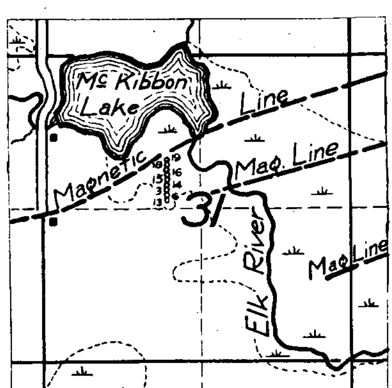


FIG. 37. Location of drill holes T. 38N., R. 2E.

Hole No.	Surface	Total Depth
19	31.3	31.3
18	32	33
16	37	38
15	45	47
14	38.5	39
3	40	40
6	40	43
13	17	21

TOWNSHIP 38N.—RANGE 9W.

This drilling was done in 1914 by H. I. Pearl. The core was not examined by this Survey. For location of holes see figure 38.

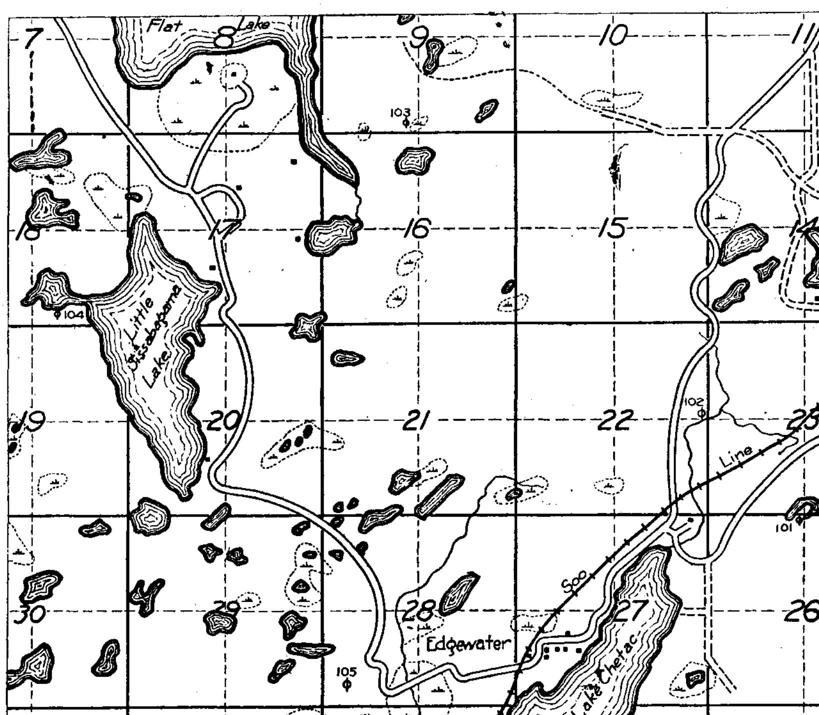


FIG. 38. Location of drill holes T. 38N., R. 9W.

Hole No. 101.

0– 50′	Surface material.
50–171′	Sandstone (Cambrian).
171–175′	Quartzite (Barron).

Hole No. 102.

0– 94′	Surface material.
94–195′	Sandstone (Cambrian).
195–435′	Alternating beds of red shale and sandstone with conglomerate from 330–345′ (?). (All Cambrian)

Hole No. 103.

0–279′	Surface material.
279–282′	Sandstone (Cambrian).

Hole No. 104.

0–284′	Surface material.
284–287′	Sandstone (Cambrian).

Hole No. 105.

0–184′	Surface material.
184–450′	Sandstone (Cambrian).

Summary.—These records indicate nothing as to the presence of the Barron quartzite west of the branch or south of the main line of the Soo Line, and nothing concerning the formation underlying the Barron in the extreme eastern portion of the township.

TOWNSHIP 39N.—RANGE 1W.

This drilling was done in 1917 under the direction of O. W. Wheelwright. Location of holes is shown by figure 39.

Hole No. 201.

0– 52′	Surface material.
52– 82′	Medium grained gneissoid pink granite.

Hole No. 202.

0– 40′	Surface Material.
40– 77′	Magnetitic, hornblende biotite schist. The thin section shows the schistosity to be well developed, with brown biotite marking the cleavage planes. Feldspars and hornblendes are more or less altered to fine mineral aggregate. Large pale green hornblendes are poikilitically intergrown with feldspar, titanite, magnetite, and rutile, a texture believed in this case to indicate igneous origin. The biotite, titanite, magnetite, and rutile are all closely related to the hornblendes. A second thin section taken from the same hole shows a rock which is perfectly fresh, shows no schistosity

and contains the same variety of hornblende with alkalic plagioclase feldspar. None of the feldspars or hornblendes are altered and magnetite is the only accessory of consequence. This rock is a fine grained diorite and is believed to be the unsheared original rock from which the above was derived.

Hole No. 203.

0– 37′ Surface material.

37– 51′ Gneissic pink granite similar to that in hole No. 201.

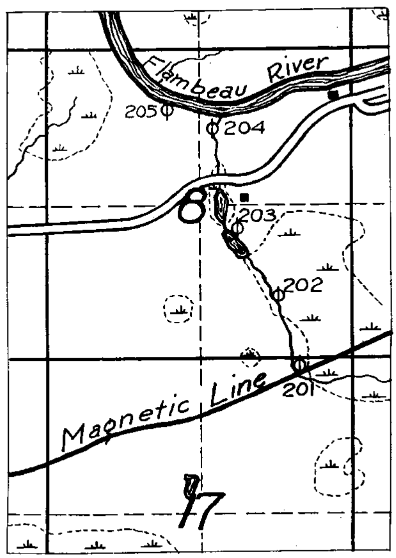


FIG. 39. Location at drill holes
T. 39N., R. 1W.

Hole No. 204.

0– 75′ Surface material.

75– 93′ Serpentinic dolomite. The thin section shows the rock to be composed essentially of carbonate which usually occurs in large individuals. Most are clear although some are cloudy. Each shows twinning which gives brilliant bands of high interference colors. Serpentine is present in considerable quantity, and muscovite is also notably abundant.

Hole No. 205.

0– 83′ Surface material.

83– 93′ Dolomite intruded by diorite. The thin section of the intrusive shows a fresh fine grained rock exhibiting a rough schistosity. Microcline, pale brown biotite and a colorless pyroxene, the essential minerals present suggest a close relation to the intrusive described from hole No. 202. The intrusive relation with the dolomite is not shown in the section but the serpentinization of the dolomite and the diopside of the intrusive would tend to support that relationship. Magnetite is entirely absent from this slide.

Summary.—It is believed that the attraction along the magnetic line is due to the hornblende diorite schist whose relation to the granite of hole No. 201, directly on the line is undetermined. The three thin sections of rock which are probably of the same general formation show cause for attraction only in hole No. 202. Magnetite occurs in the diorite here, especially in the more schistose phase. It is possible that in the contact phase of the diorite or in the zone, which possibly originated where the rock has been sheared against the granite that magnetite has been concentrated to an extent sufficient to give rise to attraction. The attraction is not caused by an iron formation. However, sediments of probable Huronian age were located in the holes farthest north, and if the succession is similar to that on the Gogebic Range further north, then the other members of the series may exist off to the north of the dolomite. Two possibilities arise in this connection which should be considered in planning further drilling. One is the possibility that the iron-formation may be non-magnetic, the other that the iron formation though magnetic is further removed from the dolomite discovered in holes 204 and 205. In the latter case the magnetic area through sections 1, 2, 3, of 39N.—2W. may be underlain by iron formation. The former possibility, however, has more advantages since the drilling may be planned in the light of the data obtained in holes 204 and 205 and this procedure would be extending an already discovered formation into an area unknown but possibly Huronian and toward an area of promising attraction. A line of holes north of 205, across section 5, ending possibly with one on the magnetic area referred to above would be most advisable.

TOWNSHIP 39N.—RANGE 4W.

This drilling was done in 1917 by the Loretta Mining Company under the direction of H. I. Pearl. The location of holes Nos. 10–19 is shown in figure 40. Hole No. 9 is shown on figure 47.

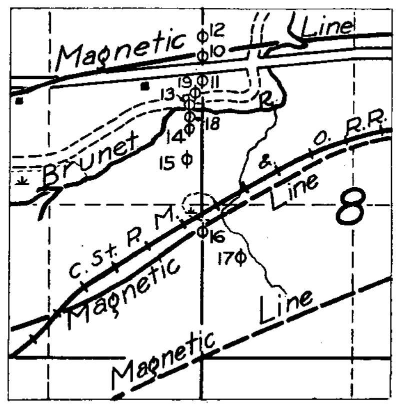


FIG. 40. Location of drill holes T. 39N., R. 4W

Hole No. 9.

0–150′ Surface material.

150–160′ Fine grained, gray, fine banded biotite quartz schist. The banding is effected by variation in mineral composition as well as size of grain. The schistosity is parallel to the banding which cuts the core at an angle of 45°. There are streaks of pyrite parallel to the banding. Garnets from ⅛″ to ¼″ in diameter have developed probably prior to most of the schistosity. Some magnetite is present to which the magnetic line may be ascribed. The original nature of this rock is somewhat problematical but the accumulated evidence suggests a sedimentary origin rather than igneous.

Hole No. 10.

0– 47′ Surface material.

47– 69′ Fine grained schistose green rock composed essentially of feldspar and dark green hornblende. The thin section shows that the hornblendes are broken and altered to a fibrous aggregate with a confused birefringence. From these shreds have been drawn away in the differential movement by which the schist was formed. Alkalic plagioclase feldspars are most abundant, and although mashed in large part, they retain relationships which are clearly igneous. Magnetite is abundant and apparently more especially in connection with the altering hornblendes. The essential fact to be recorded is that the rock is not greatly altered from its original condition as an igneous rock of dioritic nature.

Hole No. 11.

0– 40′ Surface material.

40– 51′ Black cherty slates and gray-brown finely banded cherty carbonate. The thin section from core of this footage shows carbonate in clear grains interbanded with poorly defined layers of epidote aggregate. Scattered grains of magnetite and pyrite may be seen.

51– 75′ Basic dike, very fine grained in footage 50–55′, a fine to medium grained magnetitic diabase in footage 65–70′.

Hole No. 12.

0– 50′ Surface material.

50– 65′ Fine grained green schist very similar in origin to that in hole No. 10.

Hole No. 13.

0– 50′ Surface material.

50– 80′ Banded, pinkish, white, and green, mashed siliceous dolomite. Dip of bedding about 65°.

Hole No. 14.

0– 41′ Surface material.

41– 51′ Granite.

51– 70′ Quartz-mica schist. No core examined by the Survey.

70– 74′ Diorite schist and pinkish gray irregularly banded rhyolite. The relations of these rocks are unknown but the thin section of the rhyolite is very fresh as compared with the schist. The character of the two rocks discounts this as evidence of later age of the rhyolite although it is a suggestion of the indicated relation.

Hole No. 15.

0– 59′ Surface material.

59– 70′ Diorite schist very similar in character to that in hole No. 14. Schistosity is nearly vertical in both holes.

Hole No. 16.

0–100′ Surface material.

100–115′ Fine grained black hornblende-biotite feldspar, (alkalic plagioclase) schist. Magnetite is notably abundant. The schistosity is vertical. The origin of this rock is very likely igneous, the primary nature being that of a fine grained diorite.

Hole No. 17.

0–122′ Surface material.

122–132′ Dark pinkish gray granite gneiss. Dip of gneissosity is 85°.

Hole No. 18.

0– 50′ Surface material.

50– 70′ Pink granite gneiss with small stringers of diorite schist at 55 feet.

Hole No. 19.

0– 49′	Surface material.
49– 80′	Micaceous and carbonate slates. The only core examined was for footage 70–75′ which is a hornblende diorite schist consisting of hornblende with magnetite, abundant garnet and minor altered feldspar.

Summary.—The drilling in this town should be studied with that in the township west, since holes 12, 10, 11, 19, 13, 18, 14, and 15 in this township and holes 30, 28, 27, 29, 20, 21, 22, and 23 in T. 39N.—R. 5W. are lines of holes across and for some distance north and south of the magnetic line. Holes 10 and 20 indicate that the magnetic line is due to a magnetitic green schist which from the petrographic standpoint is an altered diorite. Since this magnetic line is ten miles long and drilling clearly shows that sediments lie to the north and south of the line, and the structure of both the green schist and the sediments is much the same, it seems likely that the green schist was originally a sediment or that it was a basic igneous rock intruded parallel to the bedding of the sediments and subsequently metamorphosed with them. While the length of the magnetic line, its uniformity of trend, and the magnetic character seem to be better explained by the former hypothesis as we

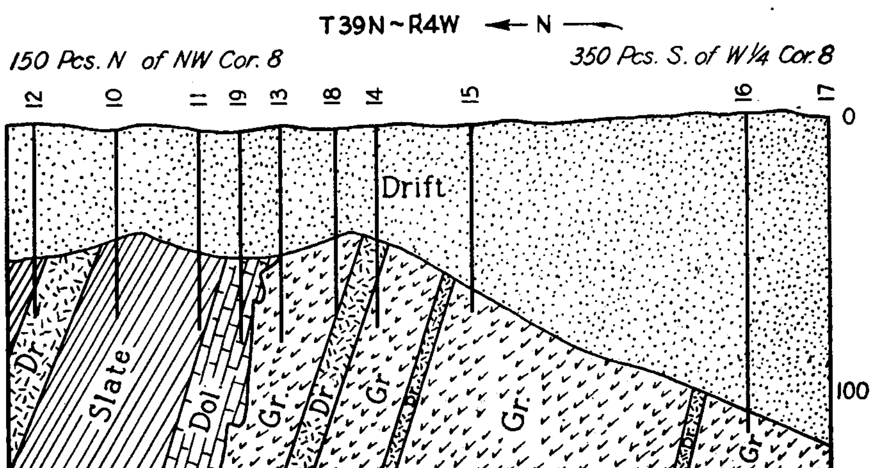


FIG. 41 ~ HYPOTHETICAL N-S CROSS-SECTION showing thickness of drift and rock formation as interpreted from results of drilling in T39-R4W

SCALE

now understand the magnetic properties of rocks, the character of the rock points very strongly to the latter hypothesis.

While nothing is known regarding the strike and direction of dip of the rocks, their distribution suggests that the strike is the same as that of the magnetic line. Assuming normal Huronian succession, the dip is steeply north and the structure in this township is as shown in figure 41. It may be that the carbonate slates in holes 11 and 19 take the place of the iron formation in the Huronian series on the Gogebic Range. Since the magnetic line is not due to iron formation and is not associated with iron formation further exploration along this line cannot be recommended.

The southern magnetic line, as indicated by the core from hole No. 16, is due to a schist of probable igneous origin.

TOWNSHIP 39N.—RANGE 5W.

The drilling in this township was done in 1917 by the Loretta Mining Company under the direction of H. I. Pearl. The location of the holes is shown in figure 42.

Hole No. 20.

0–117′	Surface material.
117–132′	Pale green, soft magnetitic, chloritic feldspar rock probably an altered phase of a fine grained diorite intrusive.
132–175′	Fine grained, dark green magnetitic hornblende schist. Schistosity 70°. In the 140–145′ interval a siliceous carbonate rock occurs as shown by the thin section. The remainder of this footage was probably of dioritic origin.

Hole No. 21.

0– 93′	Surface material.
93–112′	Very fine grained dark green siliceous slate with minute stringers of carbonate parallel to the schistosity. Schistosity and banding dips 65°.

Hole No. 22.

0– 85′	Surface material.
85– 95′	Very fine grained dark green slate. Under the microscope the thin section shows predominance of hornblendes, some fine quartz with notable quantities of calcite and pyrite scattered throughout. This rock is unquestionably a metamorphosed sediment.

Hole No. 23.

0– 74′	Surface material.
74– 84′	Dark green, coarse grained hornblende schist probably igneous in origin, i. e., a diorite intrusive.

Hole No. 24.
0– 65′ Surface material.
65– 75′ Pink gneiss, presumably Archean.

Hole No. 25.
0– 64′ Surface material.
64– 74′ Slightly gneissoid magnetitic, pyritic, diorite. Dip of gneissosity 70°.

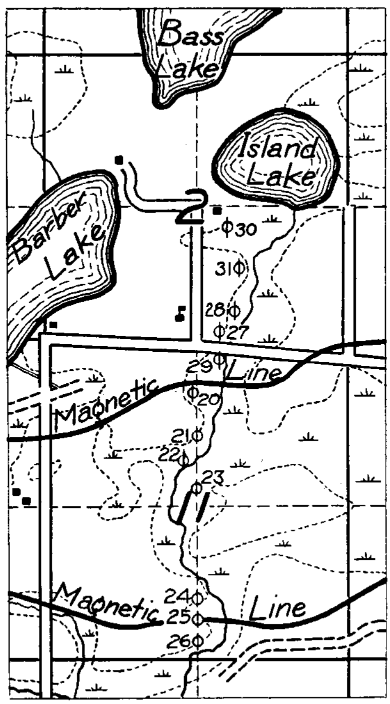


FIG. 42. Location of drill holes
T. 39N., R. 5W.

Hole No. 26.
0– 55′ Surface material.
55– 63′ Dark pinkish gray gneissoid granite similar to that in hole No. 17 in the township east. Dip of gneissosity 80°.

Hole No. 27.
0–100′ Surface material.
100–110′ Very finely banded blue black slate. The thin section shows a very fine grained slate composed largely of fine silica and a dusty black material possibly carbonaceous. Lenses of coarser quartz are interlaminated giving a banded appearance. Pyrite is rather abundant both in cubes and squeezed

out in lenses. In bands of finer grain, dusty, fibrous hornblendes are abundant. Calcite is also present. Dip of bedding 70°.

110–115′ Soft green weathered fine grained rock probably of igneous origin. It is perhaps a dike, but considering this slate series as Huronian, the disclosure of extrusives and tuffs interbedded with slates in the area east has made final decision concerning the occurrence of this rock problematical. It may also represent a basic flow.

Hole No. 28.

0–107′ Surface material.

107–115′ Finely banded blue-black slate very much like that in hole No. 27. Bedding vertical, and marked by streaks of pyrite.

Hole No. 29.

0–100′ Surface material.

100–115′ Fine grained purplish gray chlorite schist. This is sedimentary in origin and belongs in the slate series found in holes No. 27 and 28. Dip of schistosity 90°.

Hole No. 30.

0–161′ Surface material.

161–170′ Fine grained schist probably derived from a fine grained granite.

Summary.—The formation causing the magnetic line in section 11 is discussed on page 129. Figure 43 is a hypothetical section through this drilling indicating the possible structure. The slate series is given a northward dip arbitrarily. Further drilling along either line is not to be recommended since neither the formation causing the lines nor the associated formations are worthy of exploration.

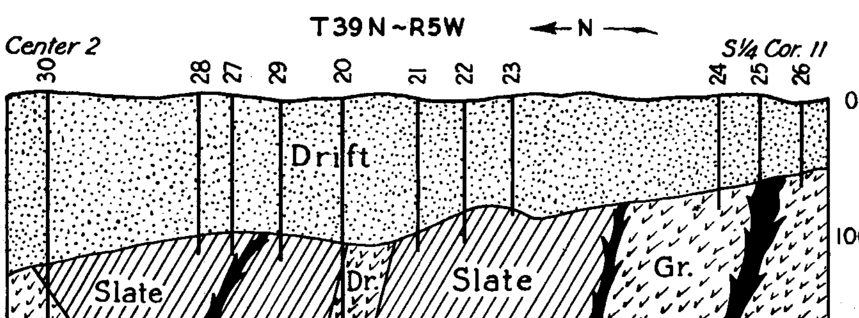


FIG. 43 ~ HYPOTHETICAL NS CROSS-SECTION showing thickness of drift and rock formation as interpreted from results of drilling in T39N-R5W

SCALE

Hor. 0 ⅛ ¼ Mile Vert 0 50 100 Feet

TOWNSHIP 40N.—RANGE 2W.

For location of holes see figure 44.

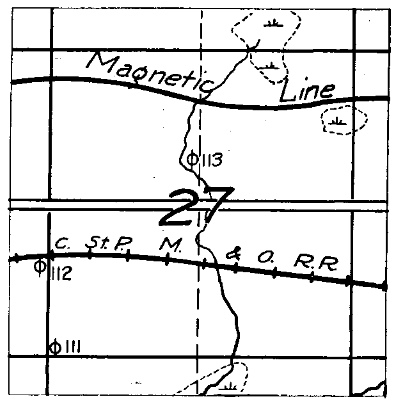


FIG. 44. Location of drill holes T. 40N., R. 2W.

Hole No. 111.

0–100′	Surface material.
100–130′	Medium to coarse grained slightly gneissoid pinkish gray granite.

Hole No. 112.

0–113′	Surface material.
113–135′	Granite similar and unquestionably the same as that in hole No. 111.

Hole No. 113.

0–105′	Surface material
105–110′	Sheared diorite.
110–120′	Fine grained pink gneissoid granite.

Summary.—Drilling in this township did not determine the character of the rock causing the magnetic line which lies north of hole 113. The purpose of the drilling south of the line is apparent on page 135 where the westward continuation of the line is discussed.

TOWNSHIP 40N.—RANGE 3W.

This drilling was done in 1917 under the joint direction of H. I. Pearl and O. W. Wheelwright. For location of holes see figure 45.

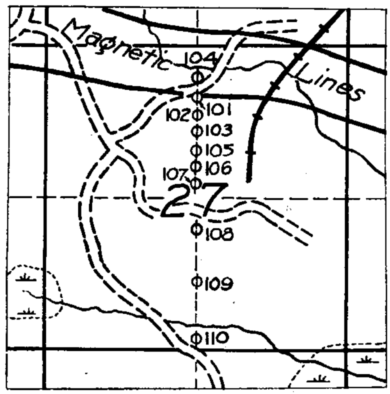


FIG. 45. Location of drill holes T. 40 N., R. 3W,

Hole No. 101.

0–207′ Surface material.

207–229′ Fine grained, greenish gray quartz—feldspar—hornblende—biotite schist with abundance of magnetite. The thin section shows an even grained aggregate of quartz, and alkalic feldspar, the individual grains of which are equidimensional and not infrequently round, and they form a compact mosaic but there is no positive proof that they have been rounded by abrasion incident to sedimentation. Long hornblendes have been developed along the shear zones and these are going over to biotite. Magnetite is abundant throughout. There is no conclusive evidence of the origin of the rock. Its fine banding is probably the evidence of greatest weight in support of a sedimentary origin. Mineral composition is well within the range of the rhyolites, but texture is hardly suggestive of igneous origin, and the hornblende alteration to biotite, a succession more characteristic of igneous schists than of sedimentary rocks. This is the formation causing the magnetic line.

Hole No. 102.

0–219′ Surface material.

219–265′ Light brown quartz mica schist. Practically the entire recovery was sludge. A thin section from footage 250′–255′ shows a muscovite, biotite quartz aggregate without sufficient evidence to conclude origin one way or the other. The succeeding core however justifies the conclusion that the schist here and at 270′–276′ is from the zone of weathering on the upper surface and from a shear zone in the gneissoid granite.

265–270′ Fresh pink gneissoid granite. Probably a small stringer from the intrusive Algonkian granite mass of the region.

270–276′ Light brown mica schist. The schist is very likely a phase of the granite gneiss of the Archean.

Hole No. 103.

0–181′ Surface material.

181–221′ Light yellow to pink, well cemented quartzite. Choppings show all grains broken.

221–256′ Medium grained light brown quartzitic sandstone with well rounded grains, and a few pebbles up to ⅛″ in diameter. Only one specimen of core was examined. This is porous from leaching action. Rhomb shaped cavities indicate a former presence of carbonate suggesting that this rock was originally a carbonate quartzite.

256–298′ Fine grained light brown cherty quartzitic sandstone, becoming more quartzitic with depth. Only one piece of core from this footage was examined. It is a very porous yellow chert from 281′. This was originally a cherty carbonate with a few quartz grains.

298–316′ Only one specimen of core. This is a light pink sugary chert. The thin section shows coarse grained bands with much finer lenses interspersed. These finer areas are crystalline and anisotropic and not amorphous.

316–331′ Quartzite similar to that above. The sludge shows an increasing proportion of rounded sand grains in this footage.

331–349′ Pink pegmatitic granite.

There is no positive evidence of bedding, but the best determination is 60°–90°. It is believed that this series is of Huronian age—since it has more characteristics in common with the Palms quartzite than it has with any other northern Wisconsin quartzite. A sandstone phase of the Palms quartzite has been described on the Gogebic Range.[1]

Hole No. 104.

0–213′ Surface material.

213–220′ Slightly gneissic salmon colored, medium grained hornblende granite.

220–222′ Fine grained magnetitic green diorite.

222–249′ Medium grained garnetiferous, pink orthoclase gneiss. Not more than suggestive of footage 213–220 in composition and texture.

[1] Van Hise, C. R., The Penokee iron-bearing series of Michigan and Wisconsin: U. S. Geol. Survey, Mon. 19, p. 154.

Hole No. 105.

0–195′	Surface material.
195–215′	Sludge only. Fine grained quartzose green schist, probably an altered slaty quartzite.
215–255′	Pinkish gray to buff colored fine grained sugary quartzite.

Hole No. 106.

0–181′	Surface material.
181–183.5	Dark gray and light green banded tremolitic dolomite, banding vertical.

Hole No. 107.

0–143′	Surface material.
143–176′	Gray green sugary quartzite, containing considerable calcite, with green streaks containing diopside, altered feldspar, calcite and sericite.

Hole No. 108.

0–195′	Surface material.
195–220′	Sludge only. Soft mica schist, probably an impure shaly bed in the original series.
220–232′	Pinkish gray crystalline limestone, an exceptionally pure marble.

Hole No. 109.

0–175′	Surface material.
175–190′	Chlorite schist, probably an impure layer in the limestone.
190–205′	Light pink and green crystalline dolomite. The bedding is not clear but may dip 10–35°.
205–214′	Chlorite dolomitic schist, the sludge indicating that the dominant portion of the rock is dolomitic.
214–235′	Green and purple schist. This section shows pale green badly weathered feldspar, oxidized reddish biotites, and quartz. Probably a small intrusive from the granite mass.
235–240′	Greenish pink crystalline dolomite.
240–245′	Mottled green and purple schist and pink and green dolomite.

Hole No. 110.

0–152′	Surface material.
152–198.5	Salmon colored granite, consisting largely of feldspar with intergrown quartz.

The above series of holes has been interpreted to have the geological section indicated in figure 46. While no definite structure can be determined from the core, it is assumed that the quartzite—dolomite series are a south dipping monocline. The age of these sediments is assumed to be Huronian.

The structure section shows an older gneissoid granite on the north which has been intruded by a small diorite dike. Upon this mass the quartzite was deposited, its basal portion probably poorly

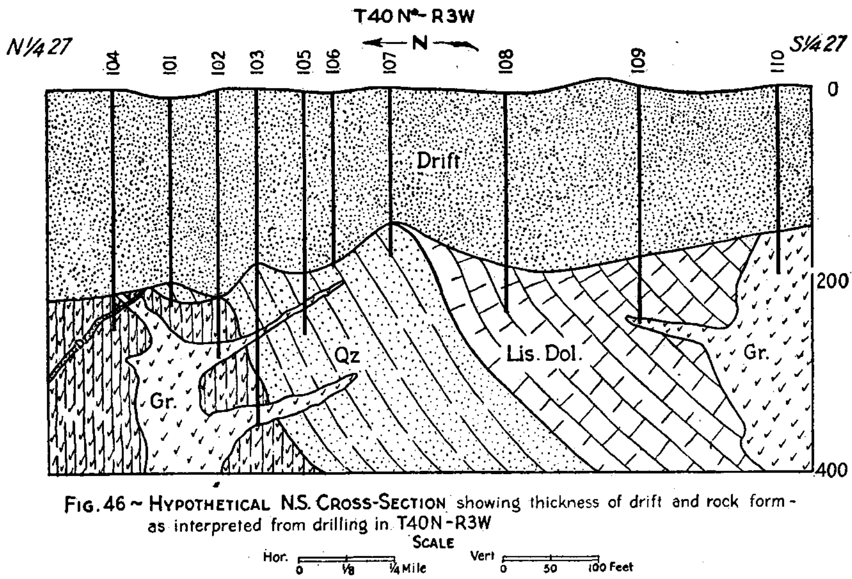


FIG. 46 ~ HYPOTHETICAL N.S. CROSS-SECTION showing thickness of drift and rock form- as interpreted from drilling in T40N-R3W
SCALE

sorted and containing abundant feldspar and magnetite. This formation is apparently extensive, having a thickness of between 1000 and 1500 feet. Its upper horizons are slightly dolomitic. The dolomite or limestone contains shaly, impure layers. This is indicated by the chloritic, shaly sludge. The thickness of this formation is close to 2000 feet, as here interpreted, a very extensive formation.

TOWNSHIP 40N.—RANGE 4W.

This drilling was done in 1917 by the Loretta Mining Co., under the direction of H. I. Pearl. Figure 47 shows the location of holes 1–8 in this township, and hole 9 in T. 49—4W.

Hole No. 1.

0– 70′	Surface material.
70– 77′	Sludge only. Pink magnetitic granite gneiss.

Hole No. 2.

0– 69′	Surface material.
69– 80′	Dark pinkish gray granite gneiss.

Hole No. 3.

0–101′	Surface material.

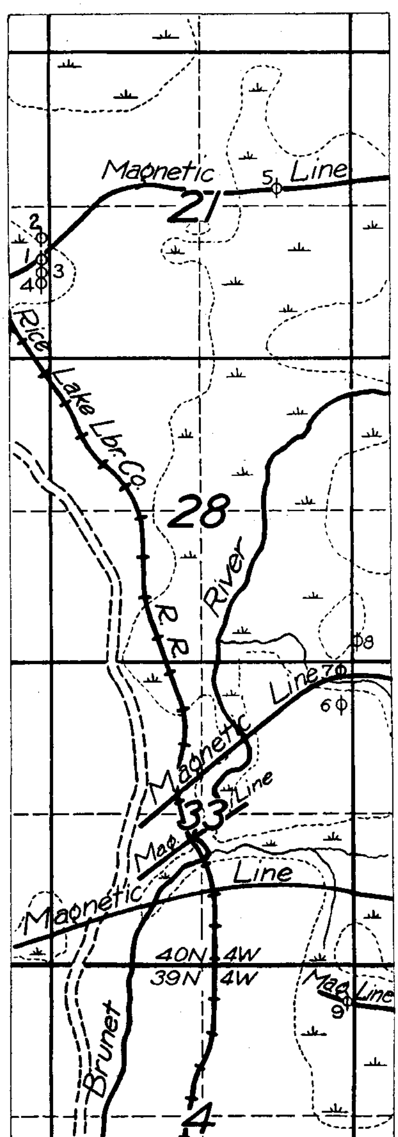


FIG. 47. Location of drill holes
T. 40N., R. 4W.

101–111′ Dark greenish gray fine grained. The thin section shows practically no feldspar, but the chlorite aggregate represents the former presence of this mineral. There is a considerable quantity of magnetite. Quartz is in no case the rounded grains of a transported mineral. The rock is probably a metamorphosed granite or sediment derived from granite, with practically no transportation.

Hole No. 4.

0–108′ Surface material.

108–111′ Light brown granite gneiss, consisting largely of biotite with some altered feldspars, and minor amounts of quartz and garnets.

Hole No. 5.

0–105′ Surface material.

105–115′ Green schist composed largely of dark green chlorite with some muscovite, biotite, and pyrite.

This drilling indicates that the magnetic line is not due to sedimentary formations but to gneisses and schists.

Hole No. 6.

0–130′ Surface material.

130–142′ Magnetitic green and purple schist. An altered igneous rock, medium to coarsely grained, consisting of altered plagioclase feldspars and large hornblendes.

Hole No. 7.

0– 94′ Surface material.

94–120′ Schistose quartzite. Dip of bedding 60–85°. A fine grained pink quartzite with pale brown biotite oriented parallel to banding. Large garnets are present.

Hole No. 8.

0–108′ Surface material.

108–112′ Pink schistose quartzite very similar in character to that in hole No. 7.

Summary.—The magnetic line in holes 6, 7, and 8 is due to the green schists which were originally a diorite. The linear character of the magnetic attraction is probably due to the fact that the diorite was a sill between the quartzite on the north and some other sediment on the south.

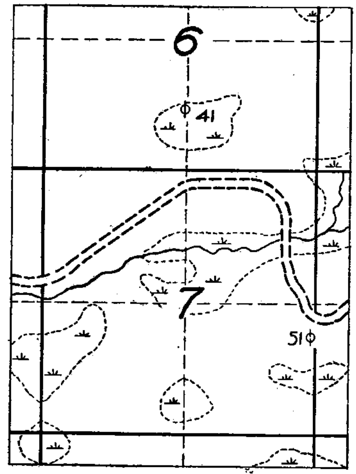


FIG. 48. Location of drill holes
T. 40N., R. 5W.

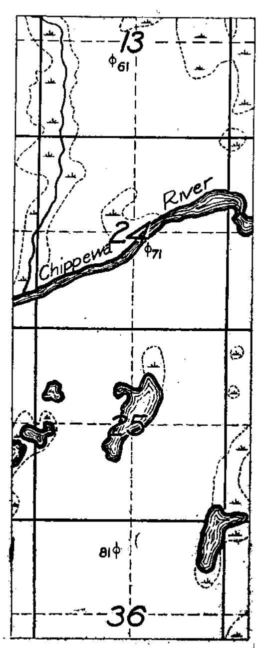


FIG. 49. Location of
drill holes
T. 40N., R. 5W.

TOWNSHIP 40N.—RANGE 5W.

This drilling was done in 1917 by the American Immigration Co. For location of holes 41 and 51 see figure 48, of holes 61, 71 and 81 figure 49.

Hole No. 41.

0–131′	Surface material.
131–141′	Pinkish gray gneissic granite.

Hole No. 51.

0–122′	Surface material.
122–130′	Dark gray gneissic granite.

Hole No. 61.

0–142′	Surface material.
142–157′	Fine grained red gneissic granite.

Hole No. 71.

0– 74′	Surface.
74–100′	Quartz-biotite-garnet schist, probably of igneous origin from a rock of granitic character.

Hole. No. 81.

0– 81′	Surface. Hole abandoned.

Summary.—Drilling in this township was not guided strictly by reference to magnetic attraction. The results of drilling at intervals of no less than a mile and at considerable distance from magnetic lines do not disclose the character of the formation giving rise to the magnetic line off to the north of the line of holes in sections 13, 24, 25, and 36. The granitic formation underlying the drift in every hole is probably a portion of the Archean complex.

TOWNSHIP 41N.—RANGE 6W.

This drilling was done in 1917 by the American Immigration Co. For location of holes see figure 50.

Hole No. 121.

0– 87′	Surface material.
87– 97′	Dark gray biotite granite gneiss and pink granite.

Hole No. 131.

0– 96′	Surface material.
96–104′	Gneiss. Core not examined in Survey office.

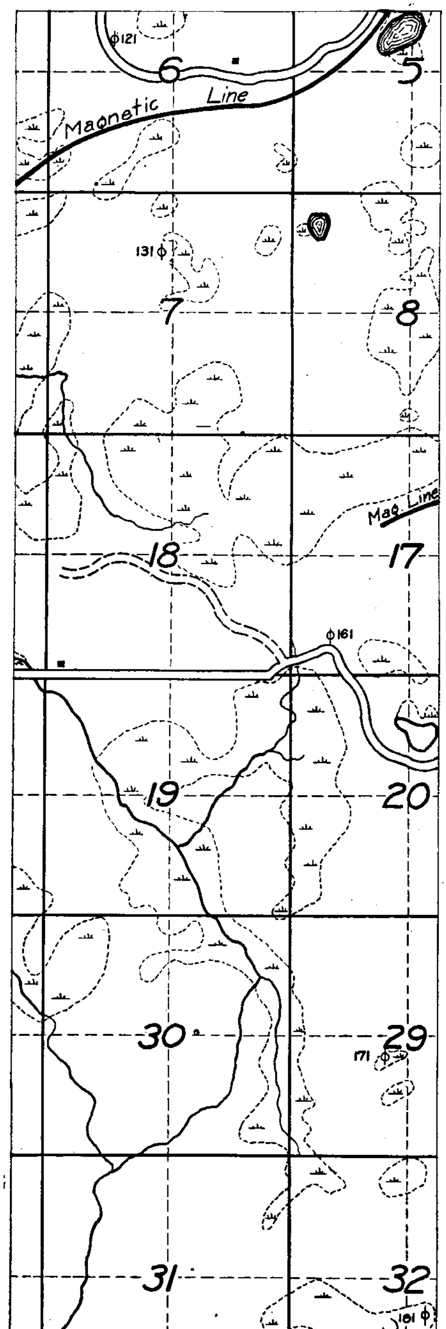


FIG. 50. Location of drill holes
T. 41N., R. 6W.

Hole No. 161.

0– 72′ Surface material.

72– 82′ Relations are not clear, but it appears that the country rock is a gneissic pink granite intruded by magnetitic pyritic diorite.

0– 63′ Surface material.

63– 73′ Hornblende schist. Schistosity in vertical.

Hole No. 181.

0– 88′ Surface material.

88– 98′ Magnetitic diabase.

Summary.—The results of drilling in this township have no direct bearing on the character of the formation giving rise to the magnetic lines, since the holes are in no case located on or within less than a quarter of a mile of the lines. The rock underlying the drift burden is granitic with hornblende schists probably of the Archean complex.

TOWNSHIP 41N.—RANGE 7W.

The core from but one hole in this township has been examined in the Survey office. This hole was drilled near the center of the NW¼ of the SE¼ of section 17 by the American Immigration Co. in 1917.

Hole No. 91.

0– 86′ Surface.

86′– 98′ Magnetitic diabase. This hole was drilled south of the north magnetic line.

The following discussion of the geology of this township was furnished the Survey by Mrs. F. C. Edson, of the Ecogal Company which conducted drilling here in 1917.

"The rocks encountered by drilling in T. 41—R. 7W., were nearly all igneous. The most predominant, and apparently the country rock, is a gabbro very closely resembling the Duluth gabbro. Above this gabbro lies thirteen or more feet of red granite, which is in turn overlain by upwards of twenty-six feet of diorite. These are folded into a syncline which pitches to the west. The pitch is gentle at the eastern end, and more steep toward the west. The center of the syncline is occupied by amygdaloid, which seems identical in character with the typical Douglas County "copper trap". One drill hole penetrated fifty feet of amygdaloid without breaking through.

West, and north of the axis of the syncline, a very fine homogeneous white sandstone was encountered. This is known to be more than seventy-four feet thick, on the shores of Round Lake.

A local deposit of ferruginous material lies unconformably on the gabbro, in Sec. 17, T. 41—R. 7W. This does not seem to be related to any of the known Lake Superior iron formations.

The whole is overlain by a mantle of glacial drift from 73 to 196 feet thick—average depth 115 feet. There is a strong negative line of magnetic attraction, and a weaker positive line, south of the negative one, striking in general NE–SW across the township."

TOWNSHIP 42N.—RANGE 7W.

This drilling was done in 1917 by the American Immigration Company. For location of holes see figure 51.

Hole No. 101.

0–138′	Surface.
138–148′	Dark gray granite gneiss.

Hole No. 111.

0–104′	Surface.
104–114′	Dark greenish gray fine grained porphyritic gneissic granite.

Hole No. 141.

0– 97′	Surface.
97–107′	Fine grained pink gneissic granite and fine grained magnetitic basalt, the latter probably intrusive into the granite.

Hole No. 151.

0–105′	Surface.
105–115′	Fine grained magnetitic diabase.

Summary.—The results of drilling in this township have but little bearing on the identity of the formation giving rise to the magnetic attraction. In fact the holes are located without direct reference to the magnetic lines. Granitic rocks, probably the Archean complex, were exposed in sections 9, 16, 26, and in 26 and 36 basic igneous rocks were discovered.

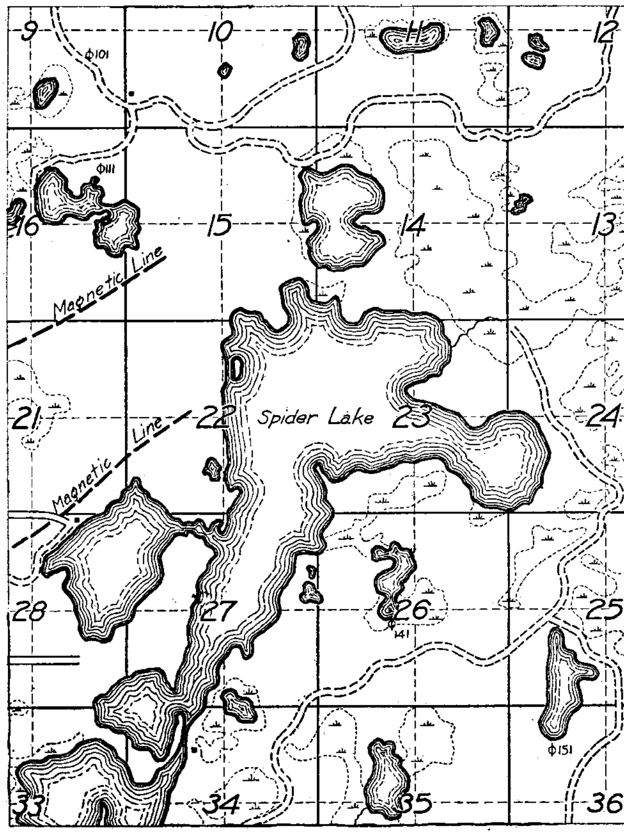


FIG. 51. Location of drill holes T. 42N., R. 7W.

SUMMARY OF THE RESULTS OF DRILLING

If this region as a whole were to be judged of its possibilities of iron formation on the basis of the results obtained above, the verdict would be that it was far from inviting for the exploration companies. In all, 106 holes were sunk, each averaging more than 125 feet in depth, and most of them on belts of attraction. These were distributed over 17 townships, but in none of them was any iron formation revealed.

At the present time, and under the present conditions, with more promising fields available, it can hardly be recommended that interest in the region be revived. The glacial drift cover is heavy. In most of the holes reported on above, the surface was over 100 feet deep. The outcrops are confined almost exclusively to the stream courses. The only way one could decide to drill at one point rather than at another would be on the basis of the results of some physical instrument. In this report and that of Bulletin XLIV, the results of a complete magnetic survey are presented. It was on the belts and areas of magnetic attraction presented in Bulletin XLIV that most of the drill holes were placed. These showed the magnetic attraction to arise from igneous rocks or metamorphic rocks of igneous origin. If these attractions are fair samples of the remaining ones, then there can be little interest in them as indicators of iron formation. Whether these are fair samples or not may be judged from the fact that they were selected not by any critical diagnosis because it is a physical impossibility to determine the character of a rock by its magnetic attraction. In most cases drilling was done either because of ownership or accessibility.

There would seem to be but one hope with any support at all. In the course of the drilling in T. 39N.—1W., T. 39N.—4W. and 5W., and in T. 40N.—3W., Huronian quartzite, dolomite, and black slate were encountered. It is possible that these are western extensions of the formations occurring in the Turtle Range. The latter extends for 76 miles from T. 41 and T. 42—R. 1W., northeastward across the state boundary and into Michigan. The geology of the range is described by Allen and Barrett.* There are two apparently unconformable series. The lower consists of a quartzite, a dolomite, and a mica schist. The upper comprises a quartzite, an iron formation, and a black slate. In the drilling last referred to, there were parts of both series, apparently. The question why the iron formation was not encountered can be answered by appealing to erosion, intrusion, or failure of original deposition. But, there remains the possibility of finding an iron formation related to this series. It is an outside chance, and with the additional fact that the iron formation of the Turtle Range has never been rich enough to work, it might well be said that this region is not of great interest to the exploring company.

There is one case of drilling not included within the above category. This has to do with the exploration east of Round Lake in T. 41N.—R. 7W. The magnetic attraction here was drilled and according to the report quoted above, the drill encountered Keween-

* Allen, R. C. and Barrett L. P., Mich Geological Survey, 1914.

awan igneous formations. The question to be raised is not concerning the identity of the formations actually penetrated, but as to whether those formations give rise to the strong attraction found there. In the late years of the Survey's work, in a great many townships underlain by Keweenawan formations of all sorts, basic, acidic, intrusive, and extrusive, we have never found these formations to give attraction of the Round Lake type. This may not prove that the attraction of the latter location was not due to the Keweenawan formations, but there is good reason to believe that the Keweenawan has been upthrust from the northwest here. If this is the case, and if they are superposed upon Huronian formations including the Ironwood of the Gogebic Range, then it might well be that the attraction arises from the Ironwood and not from the Keweenawan formations. This too is an outside chance, and while it can not be recommended that further drilling be done on the basis of this theory, it is to be regretted that the drill had not been sunk deeper to explore the depth of the Keweenawan and ascertain what underlies those formations. The western extension of the Gogebic Range has never been definitely concluded. It has long been supposed to lie to the north of Lake Namekagon in T. 44N.—R. 6W., but there are reasonably good data that the formation does not come to a final end at that place. This idea is based on evidence of strong upthrusting of the Keweenawan over the Huronian. The idea in detail is expressed in connection with a map published in Bulletin 71 of this Survey.

A final point to be touched upon concerns the possibility of iron formation in the region of the Barron quartzite. This formation is commonly thought of as of Keweenawan age. This may be correct, so far as there are any proofs, but it is unlike any Keweenawan formations to be seen in outcrop where their age is clear. If the idea be held tentatively that this quartzite is of Huronian age, that it is a flat lying formation, and that the Keweenawan formations are not found for some distance to the west, there comes a suggestion that iron formation may be found to the west of the quartzite. This, however, is an area underlain by the Cambrian sandstone, which is covered by heavy drift. Drilling operations would be difficult and expensive, and with the theoretical basis of the idea, it can not be recommended that exploration be undertaken. However, as further field work is done, and as well records are accumulated it is hoped that the idea may be kept in mind as a working hypothesis.

PART II

TOWNSHIP REPORTS

TOWNSHIP 36N.—RANGE 1E.

Surface Features.—This township is an expanse of low brule and swamp, with long, gentle slopes, culminating in broad low hills. The profiles show the gently undulating topography characteristic of ground moraine. The land rises to low elevations along the north, east, and southeast. The differences in relief between the central part of the township and the higher points to the east is about 60 feet. See profiles H–I, F–G, and E–D. The general slope is to the southwest as evidenced by the direction of the main streams. Cranberry and Worcester lakes occupy shallow depressions in the ground moraine. Swamps cover fully one-half of the township. In the extreme northwest corner is a small area of terminal moraine, with knob and sag topography. Another area of this type extends northeast from the south line of section 33 to near the east ¼ corner of section 27. This area is characterized by NE–SW ridges in section 27 where the relief is not over 50 feet, and by knobs and kettles in sections 33 and 34, where the relief is not more than 20 feet. Near the road corners at Worcester is another small area of terminal moraine. The railroad profile A–B shows the rise of 45 feet over this highland.

The materials of the ground moraine are predominantly silt, with some sand and gravel, and numerous boulders. In the areas of terminal moraine the materials are silt, a small amount of gravel and numerous boulders.

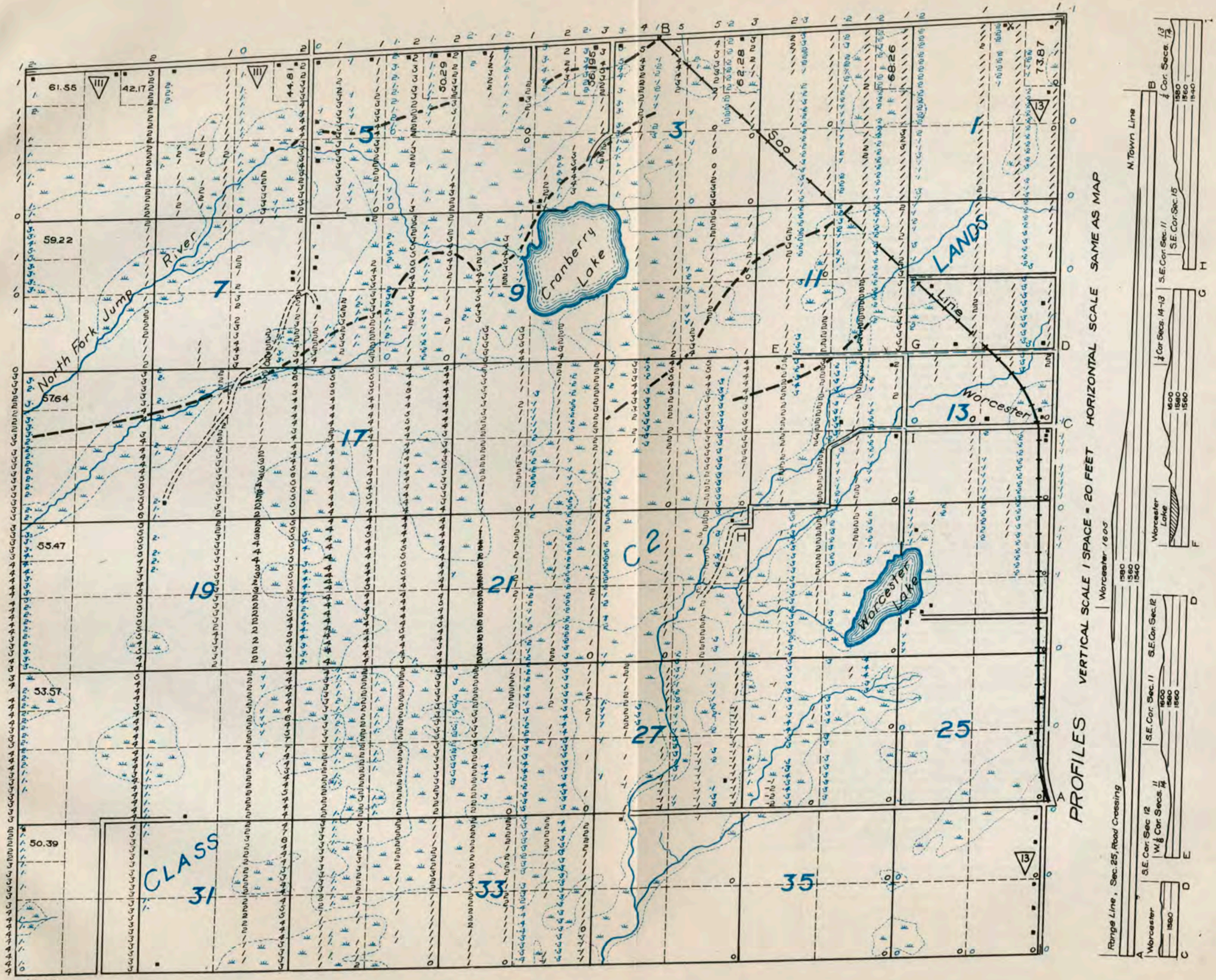
Nearly all the roads and settlement are confined to the higher land in the northern and eastern parts of the township. This is due to the large areas of swamp in other parts.

Except for small areas of hemlock and hardwood in sections 16, 17, 21, and 29, and isolated patches of spruce and tamarack, there is little timber remaining.

The thickness of drift is at least 150 feet in this township. The data in support of this conclusion is the fact that the terminal moraine of the Wisconsin ice sheet is only a short distance south, and consequently the thickness of drift in the area concerned is very great. Only one measure of this thickness, however, is available, and although it occurs near the extreme northeast corner of section 1, it is very likely that points intermediate between that location and the terminal moraine will show depth of drift which is only locally less than the maximum obtained. A well in the location given was sunk 150 feet without striking ledge. Further confirmation of this minimum is found in wells to the east and west in T. 36N.—R. 1E. A well was sunk 160 feet entirely in drift while another on the range line of T. 36N.—R. 1W. was sunk 190 feet without striking ledge.

General Geology.—There are no rock exposures in this township and unless they occur in the towns south, which is unlikely in view of the nearness to the terminal moraine, although these towns have not yet been examined, there are no outcrops in any of the adjoining towns. In order to classify the lands, however, it is necessary to judge the nature of the rocks beneath the drift cover and to do this it is necessary to rely wholly on the character of the magnetic attraction. The best interpretation which can be placed upon the attraction in this township is that it is possibly due to sedimentary rather than igneous rocks. The reason for this is the uniformity and lightness of the attraction as well as the similarity in strike and the continuity of the magnetic lines. It is further suggested by a study of the magnetic readings that the wider distribution of the characterless attraction to the south of the lines and rather abrupt drop to normal area to the north means the extension of the formation to the south. Therefore, considering these rocks as possibly sedimentary, this interpretation would imply that the formation has a uniform gentle dip to the south or consists of a series of gentle folds finally disappearing through erosion or beyond detection by instruments because of excessive overburden. Within this idea the occurrence of granite in wells at Phillips in the township north would indicate that the sedimentary formation has at that point been removed by erosion.

Magnetic Observations.—A general discussion of magnetic observations and their significance is given in chapter IV. A wide area of attraction covers nearly all of this township centering, however, in the N–S central portions. The magnetic readings along the east range line are somewhat lower than those shown along this line in the map of T. 36N.—R. 2E. Such slight differences may be expected when a traverse is repeated with different instruments on account of a difference in sensitiveness. Mild eastward attractions are found over the western half of the township, while westward attractions prevail over the eastern half. Light dip readings varying from 1° less than normal to 7° more than normal,


North Fork Jump River
Cranberry Lake
Worcester Lake
Worcester
Soo Line
CLASS C2 LANDS
1
3
5
7
9
11
13
17
19
21
25
27
31
33
35
PROFILES
VERTICAL SCALE 1 SPACE = 20 FEET
HORIZONTAL SCALE SAME AS MAP
N. Town Line
Range Line, Sec. 25, Road Crossing
Worcester 1605

36-1E

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 36 N., R. 1 E.

Survey made in July, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

R. N. HUNT, Chief of Party

M. K. DAVIS, Asst. Geologist

G. M. SCHWARTZ, Asst. Geologist

F. L. CONOVER, Asst Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

are found in all the area except in the extreme southeast. One fairly well defined magnetic line extends S 30° W from near the center of section 3 in this township, to the southeast corner of section 22 in T. 36N.—R. 1W. Parallel to this are three shorter lines. These magnetic lines are possibly due to sedimentary formations dipping gently southward. A thick, slightly magnetic formation made up of slate or iron formation or of both dipping gently southward would produce attractions similar to those in this area. The broad areas of characterless attractions might be interpreted as areas underlain by slightly magnetic slate or iron formation, and the magnetic lines as the surface expression of lenses of more magnetic slate or iron formation, or of the upturned and truncated edges of those formations. The possibility that magnetic schists give rise to this attraction should not be overlooked since in the extension of this area of attraction to the northeast diamond drilling showed the presence of magnetic hornblende schists.

Land Classification.—A general discussion of the principles of land classification employed in this work is given on page 112. All lands are placed in Class C2, as there are irregular magnetic lines, but no other indications of the presence of iron formation.

Exploration.—A moderate amount of exploration is justified on the basis of the magnetic attractions. In the exploration it should be borne in mind that the magnetic line may be due to magnetic slates and that the iron formation may be non-magnetic. A series of holes to ledge across and for some distance north and south of one of the magnetic lines would determine the character of the formation causing the less definite attractions. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey, and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in chapter VI, Bulletin XLIV of this Survey should be carefully studied.

TOWNSHIP 36N.—RANGE 1W.

SURFACE FEATURES

This township consists of two main topographic divisions. South of a line drawn through the southeast of section 1, the central parts of sections 11, 15, 16, 17, and in the northeast of section 18, there is a gently undulating ground moraine plain, draining southward to the Jump River. North of this line, with two exceptions, is an area of terminal moraine, characterized by short irregular ridges and by knobs and sags. Profiles A-B and C-A show the character of the terminal topography, which has local relief of at least 60 feet. The drainage from this area is northward to the Elk River. In both areas the slope is sufficient to drain the land fairly well. Hence the area covered by swamp is small for a recently glaciated area. In the south central part of section 19 there is a terminal moraine ridge rising to a height of 100 feet above the plain to the north and south, as shown in profile C–A. A narrow belt of swampy ground moraine about 1/3 mile in width extends along the town line from section 1 to section 4. A similar area occupies the western half of section 5 and the eastern half of section 6.

The glacial material in the ground moraine is largely silt, with numerous boulders. In the terminal moraine the material is largely sand and gravel, with very numerous boulders and some silt.

The township is well settled in the south central and southwestern parts of the plain and along the southern edge of the highland. There are about 25 miles of good roads some of which are well graded and graveled. Except for a small area of hemlock and hardwood in section 7 and 8, the township that is not cleared is covered with brule, poplar on the higher ground, and patches of alders in the low ground.

The thickness of the drift is at least 150 feet in this township. This is shown by a well in section 26 of T. 36N.—R. 2W., which is 190 feet deep and does not reach ledge. The moraine of the Wisconsin ice sheet is only a short distance to the south and bed rock in this whole area is therefore deeply covered with drift.

GENERAL GEOLOGY

Huronian sediments have been considered as the probable formation underlying the entire area except the northwest 1/8 of the township. This determination is based wholly upon inference from magnetic readings. In the northwest, the area featured by negative readings, the decision was reached that granite underlies the drift. The basis for this decision is stated in the following chapter on magnetics.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in chapter IV. Mild eastward attractions are found over all the township except in the northwest and in the south-central part. Light dip readings varying from 2° less than normal to 4° more than normal are found over much of the area.

It has been found, however, that the distribution of attraction is linear in part. Thus one fairly well defined line extends from the southeast of section 22 in this township to near the center of section 3 in T. 36N.—R. 1E. Another line of good characteristics begins near the center of section 17 and leaves the township in section 30. To the north of this is a shorter line. In the remaining area are rather extensive localities of characterless attraction of which that in the northwest is featured by negative readings. The geology of the rock surface beneath the drift has been inferred entirely upon the basis of this attraction. The magnetic line extending northeast from the southeast of 22 is continuous with the area in the town east. In general this area of attraction shows a wide expanse of characterless readings limited rather sharply on the north by a fairly continuous magnetic line. This has been interpreted to be underlain by a magnetic formation bounded on the north by the location of the magnetic line and extending southward for several miles with recurrences of dip needle maxima. A slate or iron formation dipping gently south as a monocline or repetition of gentle folds would produce attraction similar to that mapped. The line would represent the surface expression of more highly magnetic lenses; the upturned and truncated edges; or a structure bringing a narrow strip into topographic relief with the surrounding area and thus, by affecting a thinner insulation of overburden, accentuating the dip needle attraction. The lines in sections 17, 18, and 19 are ascribed to similar conditions. The uniformly negative readings in the northwest undoubtedly are the expression of a single formation of rather uniform character and having a uniform covering of drift. This area is co-extensive with an occurrence of negative readings extending north and east to the vicinity of Phillips where the feature has been correlated with the granite disclosed by drilling. It should be noted that no stand is taken as to the final significance of these negative readings.

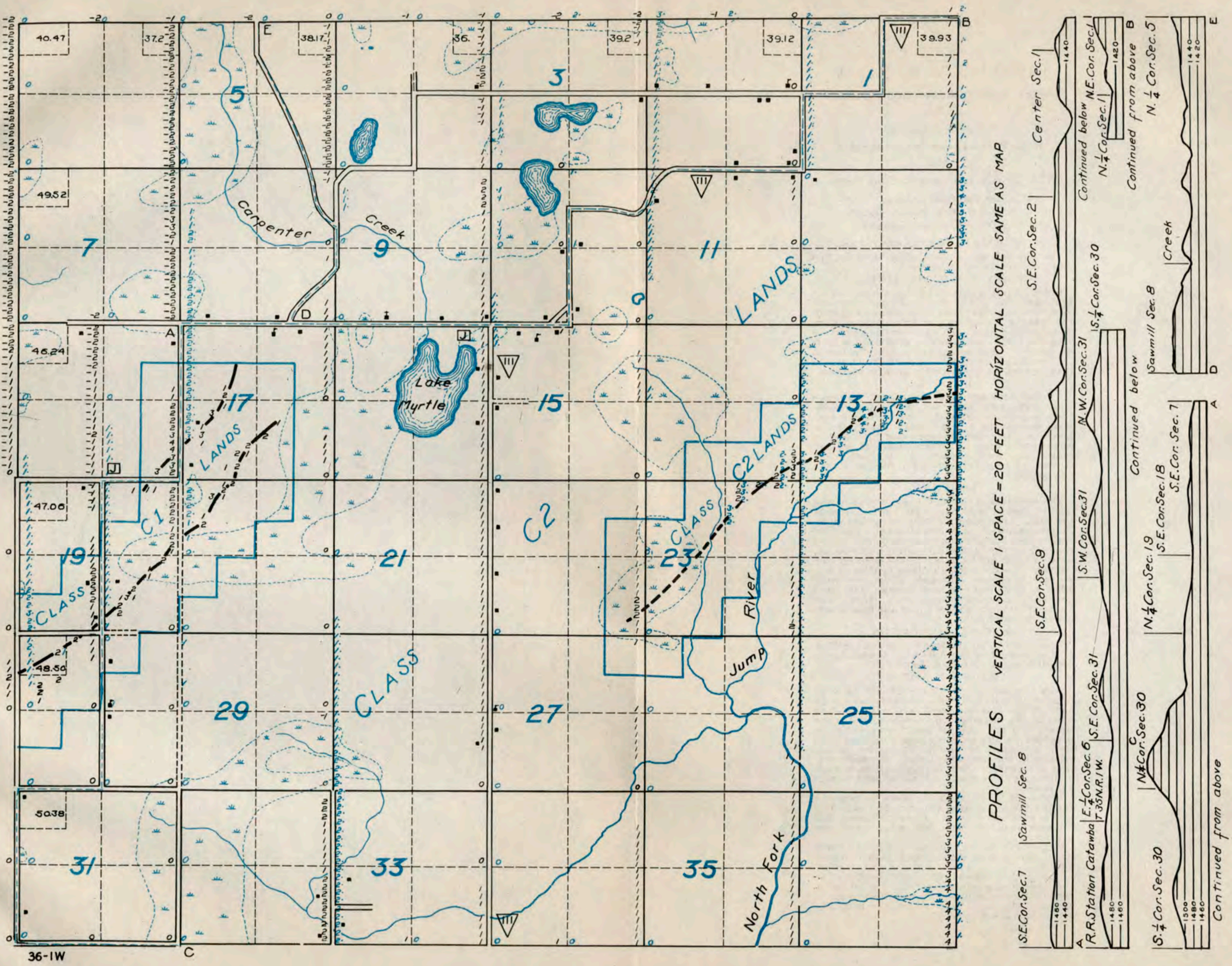
LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. Lands along the indicated magnetic lines in the western half are placed in Class C1, because it is thought possible that these lines indicate magnetic iron formation. All other lands including those along the line in the east are placed in Class C2 because the lack of magnetic lines and doubt as to the character of the rocks underlying makes more definite classification impossible.

EXPLORATION

A moderate amount of exploration is justified on the basis of the magnetic attractions. In exploration it should be borne in mind that the magnetic line may be due to magnetic slates and the iron formation may be non-magnetic. A series of holes to ledge across and for some distance north and south of one of the magnetic lines would determine the character of the formation causing the magnetic line as well as that of the formations causing the less definite attractions.

Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in chapter VI, Bulletin XLIV of this Survey should be carefully studied.



40.47
37.2
38.17
36.
39.2
39.12
39.93
49.52
46.24
47.06
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50.38
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29
31
33
35
Carpenter
Creek
Lake
Myrtle
Jump
River
North Fork
CLASS
C1
LANDS
CLASS
C2
LANDS
A
B
C
D
E
36-1W
PROFILES
VERTICAL SCALE 1 SPACE = 20 FEET HORIZONTAL SCALE SAME AS MAP
S.E.Cor.Sec.7
Sawmill Sec. 8
S.E.Cor.Sec.9
S.E.Cor.Sec.2
Center Sec.1
N.W.Cor.Sec.31
S.W.Cor.Sec.31
S.E.Cor.Sec.31
E.¼ Cor.Sec.6 T.35N.R.1W.
R.R.Station Catawba
S.¼ Cor.Sec.30
N.¼ Cor.Sec.30
N.¼ Cor.Sec.19
S.E.Cor.Sec.18
S.E.Cor.Sec.7
Continued below
Continued from above
Continued below
N.E.Cor.Sec.1
N.¼ Cor.Sec.1
Continued from above
Sawmill Sec. 8
Creek
N.¼ Cor.Sec.5

WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY
E. F. BEAN, DIRECTOR

TOWNSHIP 36 N., R. 1 W.

Survey made in August and September 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

M. K. DAVIS, Chief of Party
G. M. SCHWARTZ, Asst. Geologist
F. L. CONOVER, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

TOWNSHIP 36N.—RANGE 2W.

SURFACE FEATURES

This township is an expanse of low brule and swamp, with gentle slopes, culminating in broad low hills. The profile shows this gently undulating topography characteristic of ground moraine. The land is somewhat higher in the southeast, and the general slope is to the southwest as evidenced by the direction of the main streams. The ground moraine of the southern half of the township is more undulating than that of the northern half. There are few swamps in the southern half, while the northern half is nearly two thirds swamp. There are three belts of terminal moraine. One belt, averaging about ½ mile in width enters the township in sections 1 and 12 and extends southwest to southeast of section 15. This belt has few knobs and kettles, and is characterized by short ridges trending from east–west to northeast–southwest. These ridges determine the course of Skinner Creek. The second belt of terminal moraine enters the township from the east in sections 24 and 25 and trends southwest to the central part of section 35. From here it turns east, leaving the township in section 36. The northern part of this belt consists of one high ridge on the sides of which there are minor ridges. The southern part is characterized by low ridges. The third belt, extending across the northern halves of sections 20 and 21, is about ¼ mile in width and is characterized by low ridges.

The materials of the ground moraine are predominantly silt with numerous bowlders. In the areas of terminal moraine the materials are some silt, with large amounts of sand, gravel, and bowlders.

The township is well settled in the southeastern and east central parts, where there are good roads. There is very little timber left.

The thickness of the drift is at least 150 feet. This is shown by a well in section 25, which is 190 feet deep and does not reach ledge. The moraine of the Wisconsin ice sheet is only a short distance to the south and bed rock in this whole area is therefore deeply covered with drift.

GENERAL GEOLOGY

There are no rock exposures in this township and but a few exposures of granite and gneiss in T. 36N.—R. 3W., T. 37N.—

R. 2W. and T. 37N.—R. 3W. The geological inferences are based largely on the results of magnetic work. The magnetic attractions as shown by the magnetic line are such that the southeastern part of the township is mapped as possibly underlain by Huronian rocks. It is probable that granite is present in the remaining portion.

MAGNETIC OBSERVATIONS

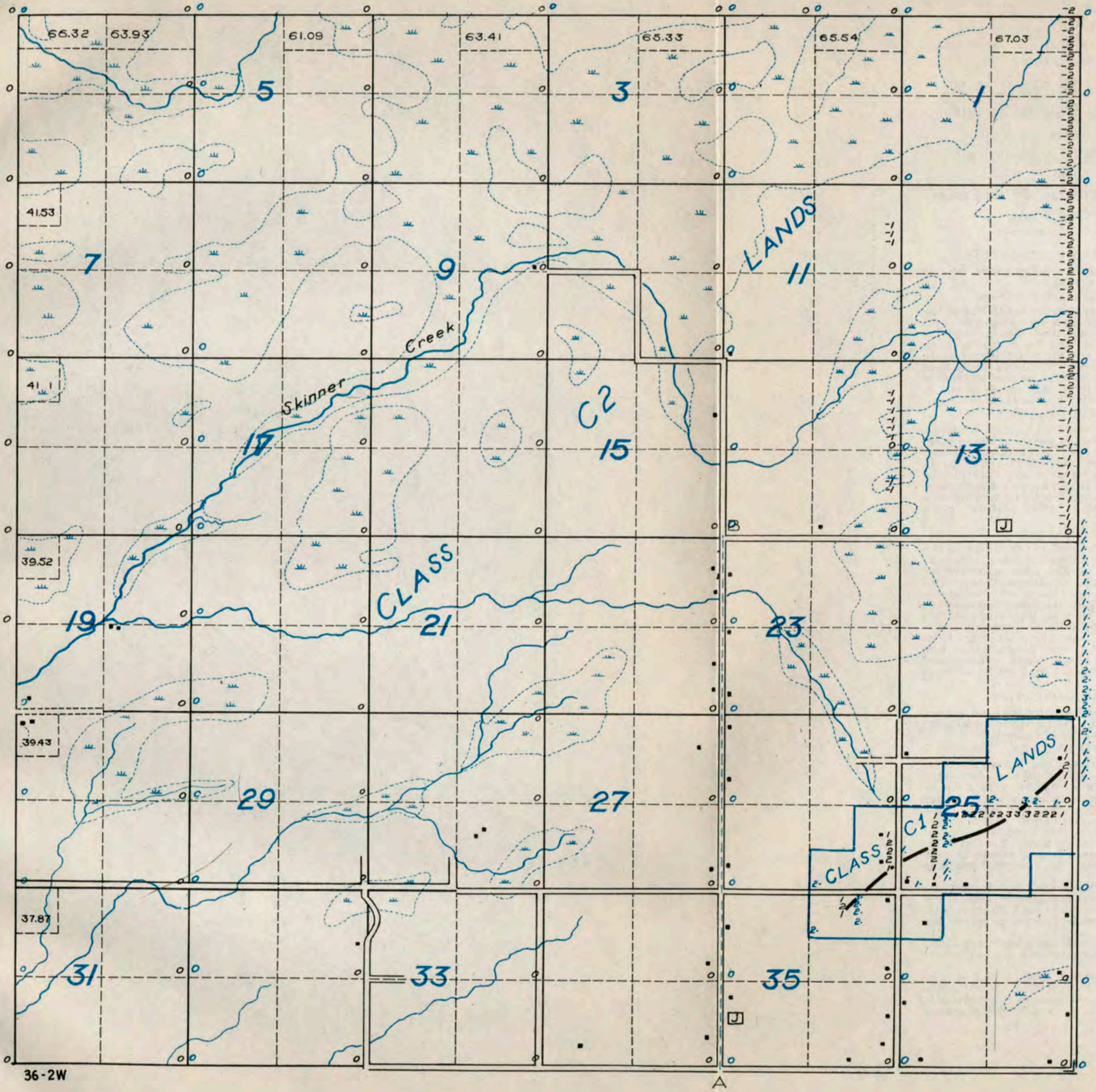
A general discussion of magnetic observations and their significance is given in chapter IV. Normal magnetic readings were found over most of the township. In the northeast there are a few negative readings. A magnetic line of good characteristics extends from the northeast of section 35 to the east line of section 25. This magnetic line and its continuation in T. 36N.—R. 1W., is possibly due to a sedimentary formation; sedimentary rather than igneous because of the uniformity and lightness of the attraction and the parallelism and continuity of the lines. A slightly magnetic formation made up of slate and iron formation or of both, would produce attractions similar to those along this line. The magnetic line might be interpreted as the surface expression of a lense of magnetic slate or iron formation. The negative attractions are probably due to some variation in granite, and granite probably underlies all the township northwest of the magnetic lines. This conclusion is based upon the fact that known areas of granite are non-magnetic or cause negative attractions, and the fact that granite outcrops are found along the Flambeau River in the townships to the west and north of this one.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. Lands along the indicated magnetic line are placed in Class C1, because it is thought possible that this line indicates magnetic iron formation. All other lands are placed in Class C2, because lack of magnetic lines and doubt as to the character of the rocks underlying makes more definite classification impossible.

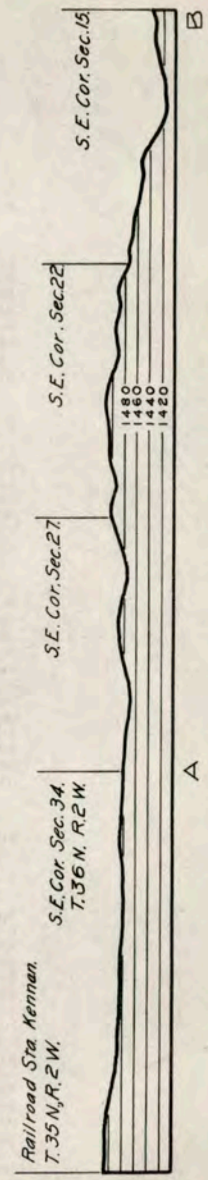
EXPLORATION

A moderate amount of exploration is justified on the basis of the magnetic attractions. In exploration it should be borne in mind that the magnetic line may be due to magnetic slates and the iron



PROFILES

VERTICAL SCALE 1 SPACE = 20 FEET HORIZONTAL SCALE SAME AS MAP



WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 36 N., R. 2 W.

Survey made in September, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

R. N. HUNT, Chief of Party

M. K. DAVIS, Asst. Geologist

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LOCATIONS.

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Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

formation may be non-magnetic. A series of holes to ledge across and for some distance north and south of the magnetic line would determine the character of the formation causing the magnetic line as well as that of the non-magnetic formation to the north and south. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in chapter VI of Bulletin XLIV of this Survey should be carefully studied.

TOWNSHIP 36N.—RANGE 5W.

SURFACE FEATURES

Nearly all this township has the gently undulating topography characteristic of ground moraine. This is a surface of gently sloping oval hills bordered by broad depressions, indicative of granite hills covered by a thin veneer of drift. Along the west side of the Thornapple River are a number of disconnected narrow sand and gravel ridges called eskers. Their trend is in general parallel to the river. Their crests are from 10 to 30 feet above the surrounding ground moraine. The old tote road follows some of these ridges in sections 18 and 19. The Thornapple River, flowing in a flood plain incised but little below the level of the ground moraine, drains the northwestern part, while the Flambeau in a valley 20 to 50 feet below the ground moraine, drains the south-eastern part of the township. In some places the Flambeau flows through a rock gorge. At Big Falls Rapids in section 35 is "the most important concentration of fall on the river." There are only a few large swamps, but small swamps occupying depressions in the ground moraine are numerous all over the township.

The materials of the ground moraine are predominantly silt, with some sand and numerous boulders.

The thickness of the drift along the Flambeau River varies from nothing to 40 feet. Since ledge is found along the Thornapple in T. 36N.—R. 6W., the average drift cover is probably not over 50 feet in thickness.

There are no settlers in the township. An old tote road follows the Thornapple and some roads are being built in the southern part.

There is much hemlock and hardwood in the northern, eastern, and east central parts of the township. The slashings which occupy the remainder have been burned over and are now grown up to poplar, birch, and alder.

GENERAL GEOLOGY

From near the center of section 35, the Flambeau River flows through a granite walled gorge for nearly half a mile. This granite not only forms the walls of the gorge but is exposed in many out-crops on the crests and slopes of small rounded hills on the east side of the river. Most of this is a coarse-grained hornblende granite with crystals of hornblende up to ½ inch in length. The rock at the northern end of the gorge is somewhat gneissic in texture. This gneissic phase weathers more easily, and as a result the river is wider and the banks are lower and less steep. In a few places this hornblende granite is cut by dikes of fine-grained red granite.

Other outcrops of hornblende granite occur along the river in section 19 of T. 36N.—R. 4W. About four tallies south and three east of the northwest corner of this section, on the bank of the river, is an outcrop of fine grained magnetic gabbro. The contact between this gabbro and the granite to the north and south is not exposed. Over this exposure negative dips of 14° were obtained, and 300 paces west on the section line negative dips were obtained, the maximum being 6°. A similar outcrop was found on the west bank of the river, in the southwest of section 24, in this township, north of Twin Islands. Negative dips of 6° were obtained here.

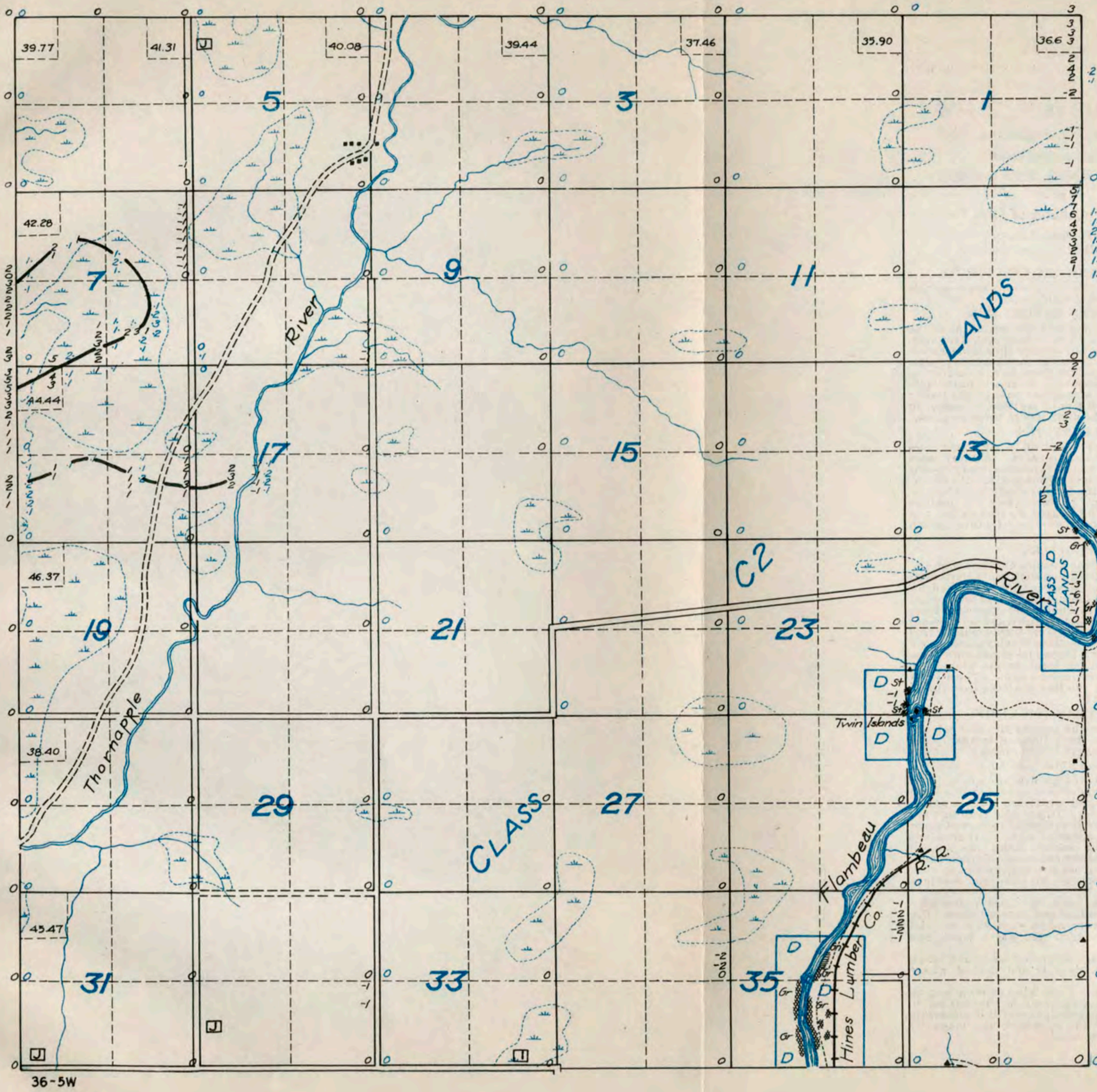
Northeast of the southwest corner of section 24 along both banks and upon Twin Islands are exposures of fine-grained hornblende schist of a dull green color. The strike of schistosity is about 75° E. Elsewhere, a slightly different phase occurs. This contains considerable quartz. A shear zone striking northeast crosses the portion of the exposure nearest the river. The indications are that the northwest side of the shear zone moved southwest with reference to the southeast side. Imbedded in the schist in masses elongated parallel to the schistosity are two lenses of granite. The quartz constituting the ground mass of this granite is brought into relief by weathering, giving the rock the appearance of a conglomerate. The contact between the acidic masses and the schists is sharp. The indications are that the acidic lenses are remnants of an intrusive into the greenstone, which have suffered deformation with the greenstone. Just north of the southeast corner of section 13 on both sides of the river are exposures of fine-grained hornblende schist. The schistosity has a strike of N. 85° E. and dips 90°. Near the center of section 25, T. 36N.—R. 6W. in the Thornapple River is a low rounded outcrop of medium-grained mica granite. There are exposed in this township the following types of rocks: (a) green schist probably a metamorphosed basic igneous rock, some phases of which seem originally to have been fine grained diorite, others fine-grained basalt, others porphyritic basalt; (b) hornblende granite which is younger than the green schist; (c) gabbro probably intrusive into the green schist and a fine grained red granite intrusive into the hornblende granite. On the basis of these outcrops it seems probable that the southern half of the township is underlain by granite and green schists. In the northern part no outcrops were found and geological inferences are based entirely on the results of magnetic work, which indicate that this area may be underlain by Huronian rocks.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in chapter IV. Magnetic lines of fair characteristics were found in section 7 and 18. More detailed work done on these lines and their extension in T. 36N.—R. 6W., creates a more favorable impression than was given by the work in 1914. It is possible that these lines indicate a sedimentary series which may be iron formation, slate or schist. As the drift cover is probably thin, the underlying rock controls the topography. Since these magnetic lines are in swamps and the higher lands border them, it seems fair to assume that these lines are the surface expression of a less resistant Huronian formation. Along the east lines of sections 1 and 12 irregular readings were obtained. These may be due to hornblende schist as "greenstone" has been reported in sections 7 and 8 of T. 36N.—R. 4W. In the southern part of the township the dial readings are all normal and the dip readings are normal or negative. The negative readings are irregular and are believed to be due to granite. This view is substantiated (a) by the fact that some known areas of granite cause similar attraction; (b) by the fact that granite bowlders are especially numerous in the drift; (c) by the fact that the topography is suggestive of granite; (d) by the fact that granite outcrops occur where stream erosion has cut through the drift mantle.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. Lands in and near the granite are placed in Class D. All other lands are placed in Class C2, since the presence of iron formation is a possibility, though it is believed that granite underlies the southern part of this township at least.



CLASS C2 LANDS
CLASS D LANDS
Thornapple River
Flambeau River
Twin Islands
Hines Lumber Co. R. R.
39.77
41.31
40.08
39.44
37.46
35.90
36.6
42.28
44.44
46.37
38.40
45.47
36-5W

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 36 N., R. 5 W.

Survey made in September, 1915

Under the direction of

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AND

E. F. BEAN, in charge of Field Parties

R. N. HUNT, Chief of Party
E. P. ROTHROCK, Asst. Geologist

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TOWN AND RANGE LINES.

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LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

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CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

EXPLORATION

A small amount of exploration in sections 7 and 18 is justified on the basis of magnetic attractions. A few holes to ledge across and to the north and south of one of the magnetic lines would determine the character of the formation causing the magnetic line. In exploration it should be borne in mind that the magnetic line may be due to magnetic slates and iron formation may be non-magnetic.

Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in chapter VI of Bulletin XLIV for this Survey should be carefully studied.

TOWNSHIP 37N.—RANGE 1E.

SURFACE FEATURES

Three different types of topography are found in this township, terminal moraine, ground moraine, and outwash. Two belts of terminal moraine cross the area. The southern belt enters the township in section 36 where it is nearly one mile in width, and leaves it in the correction forties west of sections 19, 30, and 31. In sections 35 and 36 this belt is characterized by knobs and kettles, and rises nearly eighty feet above the ground moraine to the north and nearly two hundred feet above the level of Elk Lake. Westward from there this belt is divided into two branches, the northern one of which is characterized by east and west ridges upon which are superimposed knobs and kettles. The southern branch is lower in relief and is simply a belt of irregular knobs and kettles. These branches are separated by flat areas. The northern terminal moraine belt covers the north central part of the township. It includes two wide rather short and parallel strips, which are united in sections 2 and 3 where knobs and kettles are well developed, the local relief often being as much as thirty-five feet. The relief in this belt is considerably increased by the Big Elk River which has cut its channel directly through the moraine. South of the river in section 3, besides the knobs, there are long ridges trending northeast and southwest. Beginning on the south side of the river in the NE¼ of section 3, is a large bare, steep-sloped ridge rising about 100 feet above the river. It extends to the southwest of section 3. The southern portion of this belt in sections 10, 15, and 16 is lower in relief than the northern part, and is characterized by low ridges and knobs, and shallow kettles.

Areas of relatively flat outwash plains are found along the Little Elk River around Elk Lake, in the northwestern part of the township and in the depression between belts of terminal moraine.

Ground moraine occurs in large areas lying between the belts of recessional moraine, between outwash areas and terminal moraine, in small areas surrounded by outwash. The ground moraine is characterized by gently undulating topography, and extensive areas of swamp.

The materials of the terminal moraine are largely sand and gravel, with numerous bowlders. In the areas of outwash the materials are principally sand with some gravel. In the ground moraine the materials are silt, a small amount of gravel and numerous bowlders.

The thickness of the drift is at least 100 feet, and may average more in terminal moraine areas. Wells at Phillips reach ledge at depths of 92–121 feet. Ledge is exposed by the Big Elk River, in section 3 where the local relief is about 100 feet. A well near the southeast corner of section 36 is 150 feet deep and does not reach ledge. Drilling in section 19 of T. 37N.—R. 2E., page 120 shows drift varying in thickness from 20–110 feet and averaging 63 feet.

The southern half and the northwestern part of the township are well settled and provided with excellent roads.

There is very little timber left in the township.

GENERAL GEOLOGY

Two small outcrops were found in this township. Both are in the northeast of section 3 on the Big Elk River. These outcrops are hornblende schist, in which the schistosity is nearly vertical and strikes N. 60° E. The texture varies from a fine grained perfectly schistose type to a rather coarsely crystalline type which is merely a schistose diorite. It is believed all phases are igneous in origin. The outcrop farthest up stream is cut by dikes of red granite. Erratic dip readings varying from 1½°–4° were obtained over these outcrops and the dial readings varied from 1W—2E. In Phillips four wells drilled for the city reached red granite at depths varying from 92 to 121 feet. The drilling in section 19, T. 37N.—R. 2E. shows the underlying rock to be magnetitic hornblende schist. Drilling in section 35, T. 38N.—R. 1E. shows hornblende schist, page 182. With so little positive knowledge of the character of the underlying rocks the geological inferences must be based largely on the results of magnetic work. The northwestern part of the township (see Plate I) is probably underlain by granite. This statement is based upon the finding of granite in wells at Phillips, and the large area of negative attractions in this part of the township with which the granite seems to be associated. It is possible that in the remainder of the township schists, slates, or iron formation may exist. The age of the granite is not known except that in section 3 the granite is younger than the schist.

MAGNETIC OBSERVATIONS

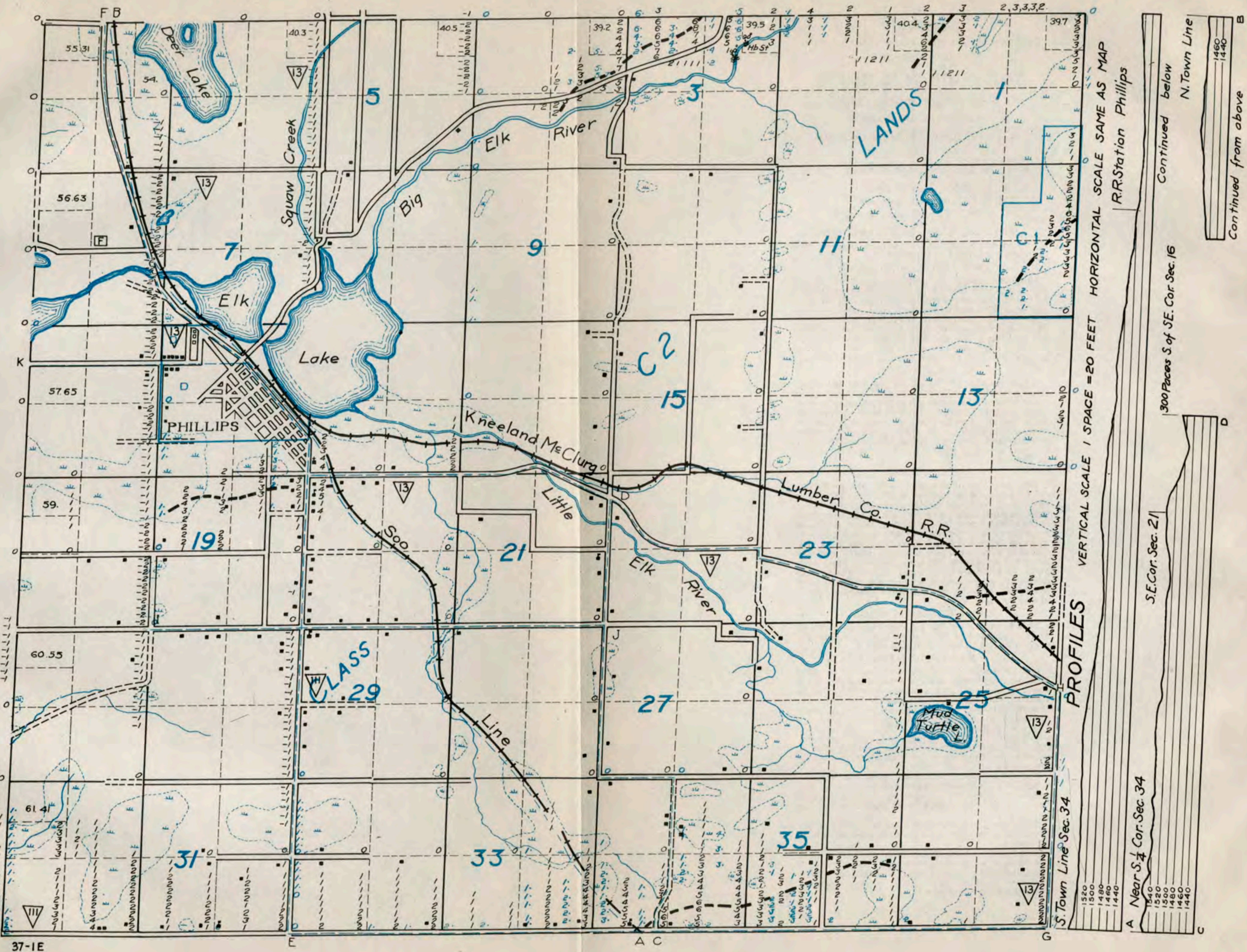
A general discussion of magnetic lines, observations, and their significance is given in Chapter IV. There are a number of magnetic lines in the township. The line in sections 34 and 35 which is continued in T. 36N.—1E. has maximum dips varying from 2° to 6°. The dial variations are not strong, but to the north of the line are in general eastward, while to the south they are in general westward. In sections 12 and 24 are short lines both of which continue for nearly two miles in T. 37N.—R. 2E. The line crossing the northwest corner of section 1 crosses section 36 in T. 38N.—R. 1E. and continues for one and one-half miles in T. 38N.—R. 2E. Drilling on this line in section 31, T. 38N.—R 2E. shows that the magnetic line is due to magnetic hornblende schist, p. 122. The line in sections 3 and 4 continues for nearly one and one-half miles in T. 38N.—R. 1E. The trend of this line is nearly parallel to the strike of the schistosity of the schist which lies about one-fourth of a mile south of this line in section 3. The maximum readings along this line are higher and the readings are somewhat more erratic than along the other lines. It is believed that the magnetic lines in this township are due to schists rather than to intrusives because of the lightness and uniformity of the attractions and the parallelism and continuity of the lines. A thick, slightly magnetic formation made up of schist, slate, or iron formation, slightly folded, would produce such attractions. The magnetic lines may be regarded as the surface expression of lenses of more magnetic schist, slate, or iron formation. The negative attractions in the western part of the township are probably due to granite.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. All lands are placed in Class C2, as there are irregular magnetic lines, but no other indication of the presence of iron formation.

EXPLORATION

The results of drilling in adjoining townships would discourage exploration in this township. It should be borne in mind, however, that while the magnetic lines may be due to magnetic schists there



Deer Lake
Squaw Creek
Big Elk River
Elk Lake
PHILLIPS
LANDS
CLASS
C1
C2
Kneeland McClurg Lumber Co. R.R.
Little Elk River
Soo Line
Mud Turtle L.
1
3
5
7
9
11
13
15
19
21
23
25
27
29
31
33
35
37-1E
PROFILES
VERTICAL SCALE 1 SPACE = 20 FEET HORIZONTAL SCALE SAME AS MAP
R.R. Station Phillips
Continued below
N. Town Line
Continued from above
300 Paces S of SE. Cor. Sec. 16
S.E. Cor. Sec. 21
Near S. 1/4 Cor. Sec. 34
S. Town Line Sec. 34

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

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Survey made in June, 1915

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may be non-magnetic Huronian rocks parallel to the schists. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey, and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific method of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in Chapter VI, Bulletin XLIV of this Survey should be carefully studied.

TOWNSHIP 37N.—RANGE 1W.

SURFACE FEATURES

This township is in general a great expanse of brule and swamp, with the gently undulating topography characteristic of ground moraine. The main topographic feature is the belt of terminal moraine which enters the township in section 12 and leaves in section 32. This moraine which varies from one-half mile to one and one-half miles in width, is composed of parallel ridges, separated by areas of slight relief. The ridges are narrow, with steep slopes, and a local relief averaging about forty feet. In places this belt is characterized by knob and sag topography. In sections 1, 4, and 6 are narrow tongues of terminal moraine extending into this area from the north. The westward extensions of the terminal moraine belts described in the southern part of T. 37N.—R. 1E., extends into sections 24, 25, 26, and 36. The Big Elk River crosses this area and controls the drainage which is sluggish except where bowlders obstruct the streams.

The materials of the ground moraine are predominantly sand, with some silt and numerous bowlders. In the areas of terminal moraine the materials are largely sand, with some gravel and numerous bowlders.

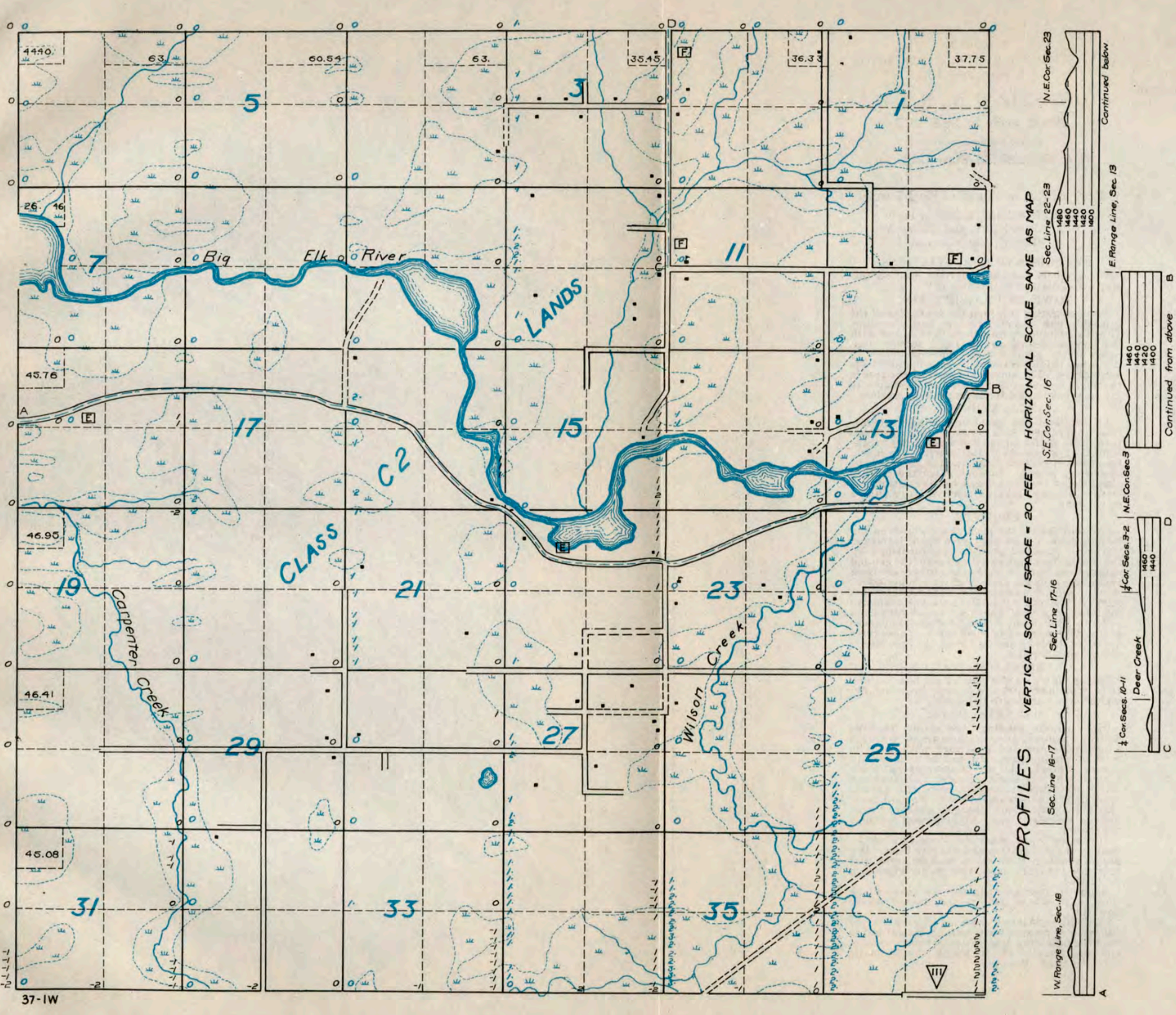
The main travelled roads are excellent. The best settled parts are the northeastern and south-central.

Except for a few small areas of hardwood and hemlock, and of cedar, all the valuable timber has been cut.

The drift probably averages 100 feet in thickness. No rock outcrops were found, and no wells are reported to reach ledge.

GENERAL GEOLOGY

There are no rock exposures in this township, hence geological inferences must be based upon information concerning adjoining townships and upon magnetic data. Granite is found in wells in Phillips, and in outcrops in T. 37N.—R. 2W., T. 38N.—R. 1W., and T. 37N.—R. 1E. Although very little magnetic attraction was found throughout the township sections 33, 34, 35, and 36 appear to be areas of light attraction related on the east and southeast to the magnetic area of T. 36N.—R. 1E. On the basis of the evidence at hand it seems safe to assume that this township with the ex-


44.40
63.
60.54
63.
35.45
36.33
37.75
45.76
46.95
46.41
45.08
5
3
1
7
11
17
15
13
19
21
23
29
27
25
31
33
35
Big Elk River
CLASS C2 LANDS
Carpenter Creek
Wilson Creek
37-1W
PROFILES
VERTICAL SCALE 1 SPACE = 20 FEET
HORIZONTAL SCALE SAME AS MAP
W. Range Line, Sec. 18
Sec. Line 16-17
Sec. Line 17-16
S.E. Cor. Sec. 16
Sec. Line 22-23
N.E. Cor. Sec. 23
Continued below
E. Range Line, Sec. 13
Continued from above
N.E. Cor. Sec. 3
¼ Cor. Secs. 3-2
¼ Cor. Secs. 10-11
Deer Creek

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 37 N., R. 1 W.

Survey made in June, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

H. D. WAKEFIELD, Chief of Party

E. A. KRONQUIST, Asst. Geologist

R. W. BROWN, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

ception of the strip in the southeast where Huronian rock may be found is part of a large granite area.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in Chapter IV. Irregular mild positive and negative attraction of the dip needle occur in several places, but none of these attractions can be connected into definite lines.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. All lands are classed as C2, although believed to be underlain by granite. Since evidence of underlying granite is not positive, D classification is not employed.

EXPLORATION

Since all the known evidence indicates this to be a granite area, exploration is not recommended.

TOWNSHIP 37N.—RANGE 2W.

SURFACE FEATURES

This township consists largely of a featureless ground moraine plain. South of the Elk and Flambeau Rivers the topography is very flat, swamps occupying about one-half the area. The upland areas are small and rise but a few feet above the swamp. North of the rivers the proportion of swamp is smaller, and the topography is gently undulating. In the northern part of sections 1, 2, and 3 is the southern edge of a terminal moraine. This belt is characterized by knobs and kettles. The local relief varies from 15 to 35 feet. In sections 5 and 6 is a narrow ridge of terminal moraine, characterized by knobs and kettles, and having a local relief of 20–40 feet. The profile shows (a) the generally level upland surface, (b) the valley of the Flambeau River, which is nearly 50 feet below the upland, (c) the more rugged terminal moraine topography in section 6.

The materials of the ground moraine are predominantly silt with a small amount of sand and some bowlders. In the areas of terminal moraine the materials are silt, sand, and gravel with numerous bowlders.

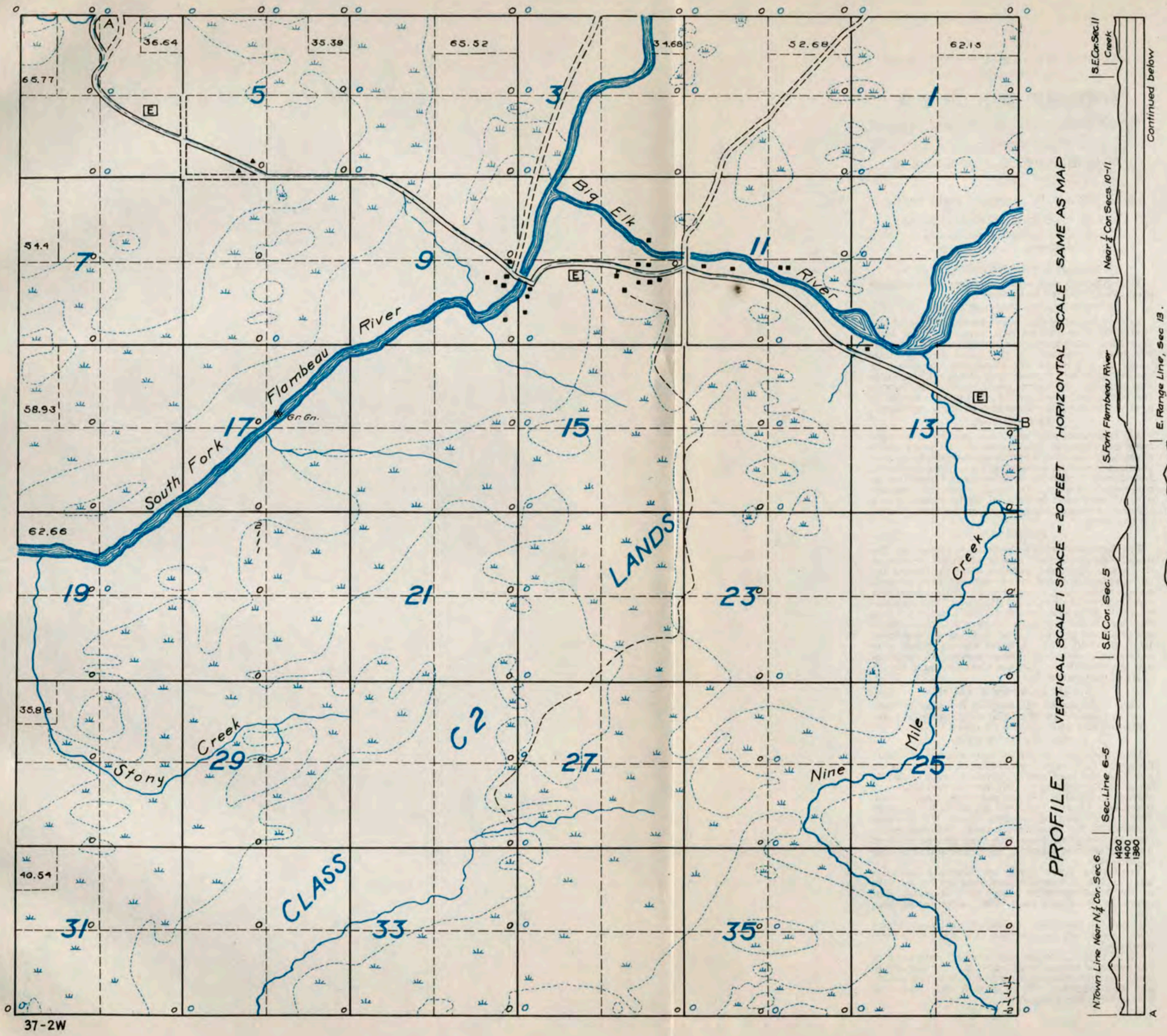
There is a well graded road from Phillips to Merrill's Resort on the Flambeau in section 9. From this place to Connor's Lake in T. 38N.—R. 3W., there is a tote road, that is being repaired and will eventually be a good automobile road. All the settlement is along the Flambeau Road, the lack of roads and the swamps having prevented settlement elsewhere.

The greater part of this township has been cut over, burned, and is now grown up to poplar. The largest belt of timber is in sections 5, 6, 7, 17, and 18, where there is a heavy stand of hardwood and hemlock. There are scattered areas of hardwood and hemlock in sections 21, 22, 23, and 32. In the swamps alder and grass are most common, though there are small areas of tamarack, spruce, and cedar.

The thickness of drift probably averages a little less than 100 feet. As no wells reach ledge, this estimate is based upon the slight relief, and the fact that granite outcrops on the Flambeau.

GENERAL GEOLOGY

There is an outcrop of granite gneiss on the north bank of the Flambeau and jutting into the stream about 800 paces south and



South Fork Flambeau River
Big Elk
River
Creek
Nine Mile
Stony Creek
CLASS C2 LANDS
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
36.64
35.39
65.52
34.68
52.68
62.13
65.77
54.4
58.93
62.66
35.86
40.54
Gr. Gn.
A
B
E
PROFILE
VERTICAL SCALE 1 SPACE = 20 FEET
HORIZONTAL SCALE SAME AS MAP
N. Town Line Near N¼ Cor. Sec. 6
Sec. Line 6-5
S.E. Cor. Sec. 5
S. Fork Flambeau River
Near ¼ Cor. Secs. 10-11
S.E. Cor. Sec. 11
Creek
E. Range Line, Sec. 13.
Continued below
Continued from above B
1420
1400
1380

37-2W

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 37 N., R. 2 W.

Survey made in August and October, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

H. N. EIDEMILLER, Chief of Party
E. A. KRONQUIST, Asst. Geologist
R. W. BROWN, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

150 paces east of the N¼ corner of section 17. Since but one outcrop of granite was found, the character of rock underlying the township must be inferred from the character of the magnetic readings, and our knowledge of the surrounding townships. Abnormal magnetic readings are entirely lacking and granite is known to occur along the streams in the townships north, west and southwest of this. Therefore it is believed that all of this township is underlain by granite.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in chapter IV. No abnormal magnetic readings were found.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. All lands are classed as C2, although believed to be underlain by granite. Since evidence of underlying granite is not positive, the D classification is not employed.

EXPLORATION

Since all the known evidence indicates this to be a granite area, exploration is not recommended.

TOWNSHIP 37N.—RANGE 3W.

SURFACE FEATURES

The ground moraine which covers nearly all of this township, is characterized by stretches of very flat topography and by long gentle swells which are but a few feet higher than the swamps which occupy the depressions. In sections 6, 7, 8, and 17 is a belt of terminal moraine, with knob and sag topography. In the western part of sections 30 and 31 is another area of knob and kettle moraine, much dissected by streams. Along the North Fork of the Flambeau which cuts through this moraine, erosion of tributary streams has resulted in local relief of from 40 to 50 feet. In section 34 the South Fork of the Flambeau flows for nearly a mile over granite, making three sets of falls and rapids. The river valley here is fifty feet in depth and nearly one-half mile in width.

The materials of the ground moraine are largely silt with some sand and numerous bowlders. In the terminal moraine the proportion of sand is higher.

The drift cover probably averages no more than 75 feet in thickness, since this is an essentially level area and the river reached bed rock in many places less than 75 feet below the upland surface.

There are no roads nor settlements in this township. This is probably due to its distance from a railroad.

Except for the swamps and a few areas of poplar brule, this township is covered with hardwood and hemlock. In the swamps are spruce, alder, and cedar.

GENERAL GEOLOGY

For nearly one-fourth mile downstream from the southeast corner of section 23 there is almost continuous outcrop of granite on both banks and in the stream. This is a dark gray, medium to fine grained granite consisting of biotite, quartz, and feldspar. At the east ¼ corner of section 27 granite outcrops on both sides of the river and forms the river bed. The dominant phase here is fine grained pink granite. This is cut by narrow dikes of pink pegmatitic granite. On the south bank of the river south of the center of section 27 there is an outcrop of coarse grained grayish white granite.

In the west half of the west half of section 34 the river flows over an almost continuous bed of granite. In this distance there are three falls: one, South Falls, 400 paces N. and 150 paces E. of the southwest corner of section 34; one 150 paces east and 300 paces north of the west ¼ corner of section 34; and the third 150 paces east and 400 paces south of the northwest corner of section 34. Granite outcrops almost continuously along the river and there are small discontinuous outcrops for a distance of 100 to 250 paces back from the river. The characteristic phase is medium grained pink granite consisting of orthoclase, biotite, and quartz. At South Falls this granite is cut by several aplite dikes and by a dike of coarse pegmatite. "A little south of the center of the NW¼ of section 34, quite a large portion of the rock is a very neat gray, medium-grained, firm, regularly-fractured *hornblendic gneissoid granite,* in which the feldspar is the bluish-white, striated variety. The brilliant feldspar facets, together with the duller quartz grains among which are scattered a profusion of black mica and very dark hornblende, give to the rock a handsome variegation."[1] The bedding planes strike E. 15° N. and dip to the southward about 88°.

Outcrops also occur along the north fork of the Flambeau. 800 paces south of the NW corner of section 30 on the south bank of the river is an outcrop, which is so much rounded and broken that it was impossible to get any information regarding structure. This outcrop shows various phases grading from a hornblende schist to a granite. At the eastern end of the outcrop is a rock which appears sedimentary in origin.

The thin section shows extreme alteration by crushing and decomposition of the constituent quartz and feldspar grains. The gneissoid structure is clear, but there is nothing in the physical or mineralogical character to warrant a sedimentary determination and it appears to be a sheared phase of the granite.

About one-fourth mile north and one-fourth mile west of the south ¼ corner of section 30 there is an outcrop of hornblende schist on the south side of the river. 500 paces south and 200 paces east of the north ¼ corner of section 31 there is an outcrop of coarse grained red granite. The top of the outcrop is coarse-grained pegmatite granite. When visited in 1915 the water was high and the above described outcrop was all that could be seen. F. H. King here describes "an exposure of coarse red granite and gneiss in which the bedding planes strike E. 11° N. and dip about

[1] King, F. H., Geology of Wisconsin, Vol. IV., p. 603.

70° or 75° W. of north. The outcrop presents a total thickness of over 300 feet, 250 feet of which is the coarse red granite."[1]

From the character of the magnetic readings and the numerous outcrops it is believed that all of this township south of a line drawn from the east ¼ corner of section 1 to the northwest corner of section 30 is underlain by igneous rocks. North of this line no outcrops were found, and although the magnetic readings show no special characteristics there is no cause to condemn the presence of Huronian rocks.

MAGNETIC OBSERVATIONS

A general discussion of the magnetic observations and their significance is given in chapter IV. In the southern part of the township above described, negative dip readings are abundant. This characteristic is employed in projecting the granite area from the known outcrops associated with similar readings. The dial readings in the southwest show westward variation. In the northern part of the township the dip readings are all normal or 1° to 5° more than normal. No definite lines can be drawn, but, in the lack of evidence to the contrary, decision against the possible presence of iron formation must be reserved.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. Lands in the vicinity of granite outcrops are placed in Class D. All other lands are placed in Class C2 although as stated, it is believed that the southern part of the township is underlain by granite.

EXPLORATION

Exploration is not recommended in this township, since in the area where Huronian rocks are at all probable, the magnetic readings are so poorly defined, that intelligent placing of drill holes would be out of the question. Should exploration in adjoining areas furnish more definite information regarding the formation, exploration might then be advisable. Before any drilling is done, however, the magnetic lines should be followed very carefully.

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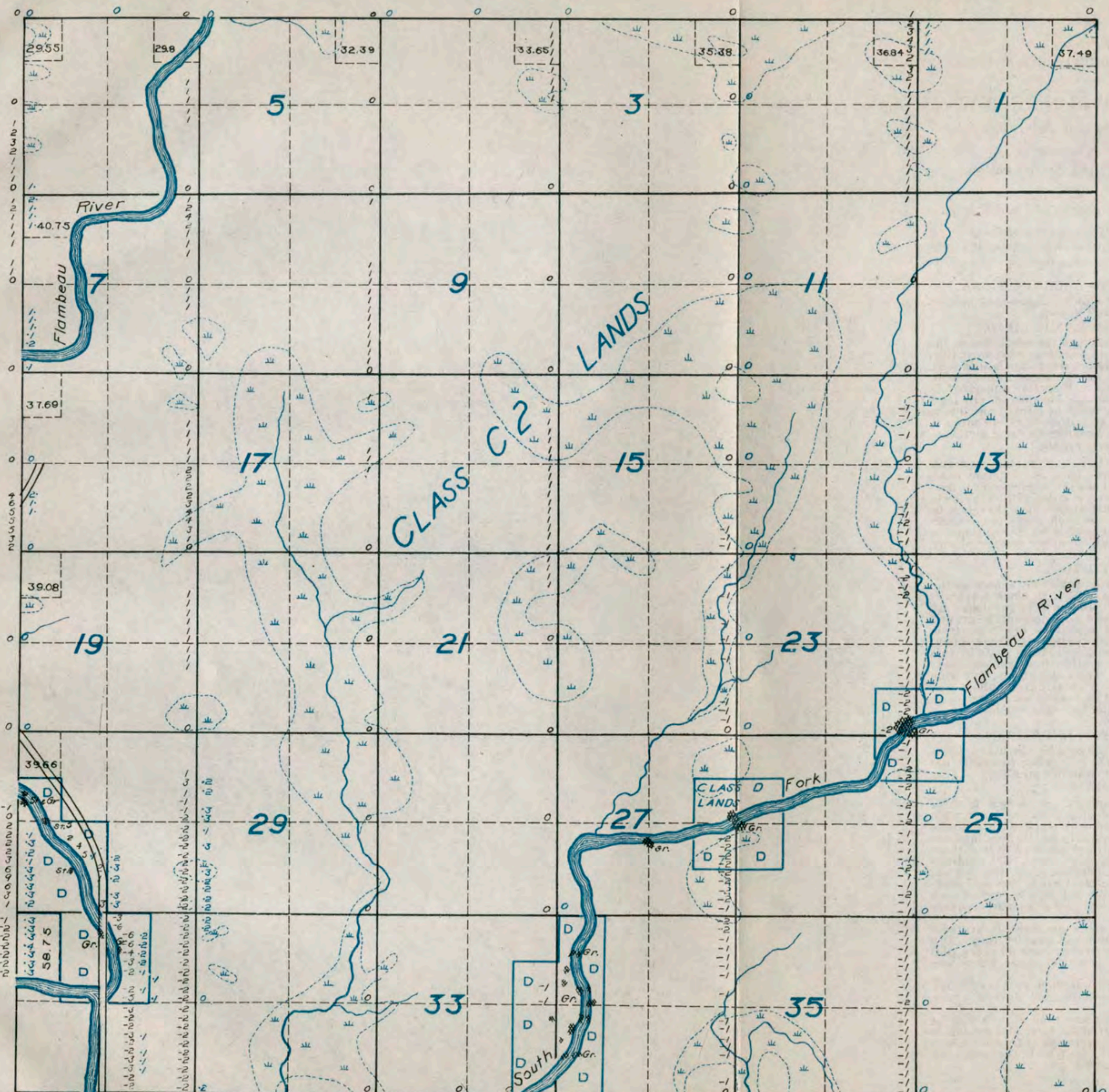
[1] King, F. H., Geology of Wisconsin, Vol. IV., p. 505.


29.55
29.8
32.39
33.65
35.38
36.84
37.49
5
3
1
River
40.75
Flambeau
7
9
11
CLASS C 2 LANDS
37.69
17
15
13
39.08
19
21
23
Flambeau River
39.66
CLASS D LANDS
Fork
29
27
25
58.75
33
35
South

37-3W

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 37 N., R. 3 W.

Survey made in July, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

H. N. EIDEMILLER, Chief of Party
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SYMBOLS AND ABBREVIATIONS.

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TOWN AND RANGE LINES.

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LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

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MAGNETIC DATA.

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Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

TOWNSHIP 37N.—RANGE 4W.

SURFACE FEATURES

The major portion of this township is ground moraine varying from nearly level to gently rolling, with a relief of seldom over ten feet. This lack of relief results in numerous swamps. In the northeast of the township is a belt of terminal moraine, extending for three miles along the range line and averaging about one and one-half miles in width. Along the Flambeau in sections 35 and 36 is another belt of terminal moraine. Both areas are characterized by knob and kettle topography and a good deal of stream dissection near the rivers. The maximum relief is not over 50 feet. The level north-south undrained area through the central part of the township forms the divide between the streams flowing southeast to the Flambeau and those flowing southwest to the Thornapple and its tributaries.

The materials of the ground moraine are largely silt with some sand and numerous bowlders. In the terminal moraine the percentage of sand is higher.

The only roads are old tote roads. Except for logging railway spurs, there are no railroads. The township is unsettled and contains no clearings.

The Kaiser Lumber Company is (1915) logging in the northeastern part of the township. Except for these cuttings, a few areas of poplar brule, and the swamps, the township has a good stand of hemlock and hardwood. The swamps contain cedar, spruce, balsam, and tamarack.

The thickness of the drift is not known as there are neither outcrops nor .wells. From the fact that rock outcrops occur in T. 37N.—R. 3W., and this is an area of slight relief, it is probable that the drift cover does not average over 75 feet in thickness.

GENERAL GEOLOGY

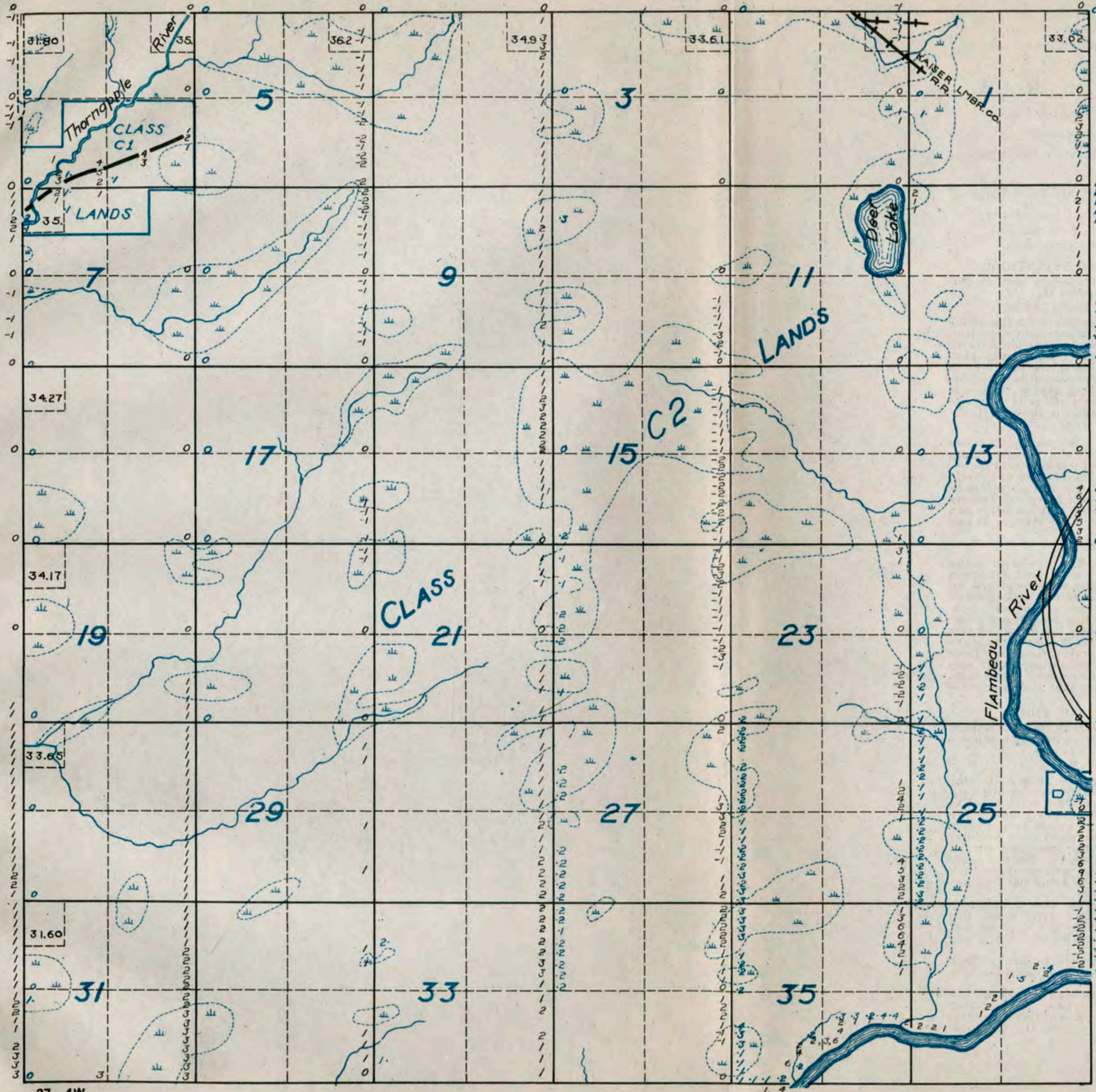
There are no rock exposures in this township, hence geological inferences must be based upon the results of magnetic work and upon the information available regarding T. 37N.—R. 3W. The character of the magnetic readings and the granite outcrops in sections 30 and 31 of T. 37N.—R. 3W. suggest the presence of granite in sections 25, 26, 35, and 36. The widely distributed magnetic readings in the remainder of the township are similar in many respects to those in the town east. Negative readings in that town were found over granites. Positive dips were found on schists within the granite areas. Therefore, there is reason for believing much of T. 37N.—R. 4W. underlain by these basement rocks. But in the absence of definite data, the area must not be considered as containing no Huronian sediments.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in chapter IV. The greatest variations from normal readings occur in section 25, 26, 35, and 36. Here the dial variations range from 1° W.—4° W. and the dip readings vary from 2° below normal to 9° above. It is believed that granites or highly metamorphosed sediments underlie this region, since the magnetic readings are erratic and rocks of this character outcrop in the two sections to the east, and are accompanied by similar magnetic readings. Extending from the northwest corner of section 7 across the southern part of section 6 is a magnetic line of fair characteristics. In the township to the west are three magnetic lines having nearly the same strike as this line. It seems possible, therefore, that this line is due to magnetic slate or iron formation. Over the remainder of the township are large areas of normal dip readings, and others of light attractions varying from 3° less than normal to 6° more than normal. This broad area of normal and light attraction is interpreted as an area underlain by slightly magnetic slate, schists, or possibly iron formation.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. Lands in the vicinity of the outcrop near the east line of section 25 are placed in Class D. Lands along the magnetic line are placed in Class C1. All other lands are placed in Class C2, since they have irregular magnetic attractions and no other indications of the presence of iron formation.


Thornapple River
CLASS C1 LANDS
CLASS C2 LANDS
Deer Lake
Flambeau River
KAISER LMBR. CO. R.R.
5
3
1
7
9
11
17
15
13
19
21
23
29
27
25
31
33
35
31.80
35.
36.2
34.9
33.02
34.27
34.17
33.65
31.60

37 - 4W

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 37 N., R. 4 W.

Survey made in July, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

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LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

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LAND CLASSIFICATION.

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MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

EXPLORATION

A moderate amount of exploration is justified on the basis of the magnetic attractions. In exploration it should be borne in mind that the magnetic line may be due to magnetic slates and that the iron formation may be non-magnetic. A series of holes to ledge across and for some distance north and south of the magnetic line would determine the character of the formation causing the magnetic line as well as that of the formation causing the less definite attractions. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in chapter VI, Bulletin XLIV, of this Survey should be carefully studied.

TOWNSHIP 37N.—RANGE 5W.

Nearly all of this township has the gently undulating topography characteristic of ground moraine. Slopes are usually long and gradual. Drainage is fairly well developed, though there are large swamps in the central part of the township, and small depressions all over the area are occupied by swamp. The Thornapple River flows in a valley cut not more than 25 feet below the upland surface. In some places the erosion by tributary streams has developed shallow ravines near the Thornapple River. There is a small area of terminal moraine in the northern part of section 2 and 3, another in the northeast of section 16 and a third in the southeast of section 1. The first area is characterized by knob and kettle topography and the others by steep ridges. The maximum relief is not over 35 feet.

The material of the ground moraine is silt with numerous bowlders. In the terminal moraines the materials are largely sand and gravel with some silt and numerous bowlders.

Except for the old tote road there are no roads in the township. There are no settlers.

The hardwood in the northwestern part has been cut and the slashings swept by fire. Except for scattered areas of recent slash and poplar, hardwood and hemlock cover the remainder of the township.

The thickness of the drift is not known, as there are neither outcrops or well borings in the township. Since outcrops do occur in the townships north and south of this and the topography and elevations of all three is much the same, it is believed that the drift cover averages less than 75 feet in thickness.

GENERAL GEOLOGY

There are no rock exposures in this township. Geological inferences are based largely on the results of magnetic work. Because of the occurrence of granite in the township north and the dip readings which are less than normal, the northwestern part of the township is believed to be underlain by granite. The character of the magnetic attractions suggests the possibility that the remainder of the township may be underlain by Huronian rocks, either magnetic slates or iron formation or both, as the magnetic readings are too uniform in character to make it probable that they are caused by igneous rocks. The structure of these sedimentary formations is probably a series of gentle folds.

MAGNETIC OBSERVATIONS

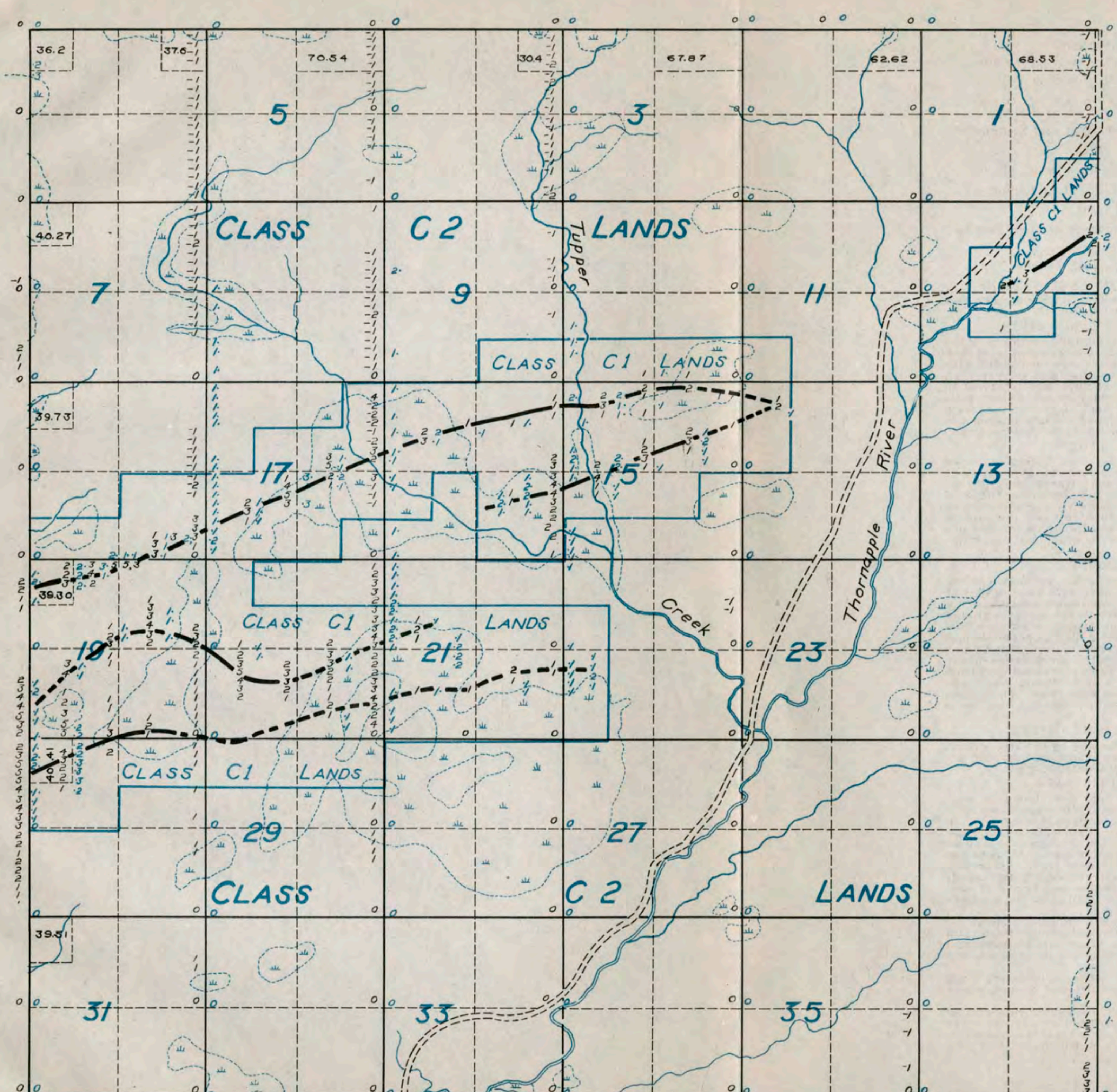
A general discussion of magnetic observations and their significance is given in chapter IV. In the northwest is an area of negative attraction which is believed to be due to granite. Entering this township in the northwest of section 19 and continuing to the northeast of section 15 is a magnetic line of good characteristics. With its extension in T. 37N.—R. 6W. this line has a length of over six miles. The line south of this has a total length of over four miles, two and one-fourth of which is in this township. A third line, nearly parallel to the second, has a total length of four miles, three of which are in this township. On section 12 is a short line which was traced for about a mile in T. 37N.—R. 4W. South of these lines the dip readings vary from 1° less than normal to 3° more than normal and the dial readings are normal. The magnetic lines are possibly due to sedimentary formations. The broad area of normal or characterless readings south of the magnetic lines might be interpreted as areas underlain by slightly magnetic slate or iron formation, and the magnetic lines as the surface expression of lenses of more magnetic slate or iron formation. That this is a Huronian area is further strengthened by the presence of iron formation and slate pebbles in the drift (page 44).

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. All lands along the magnetic lines are placed in Class C1. Since there is no information to warrant a more definite classification, all other lands are placed in Class C2.

EXPLORATION

The character of the magnetic lines justifies a reasonable amount of exploration, since this series has a length of nearly twenty miles. In exploration it should be borne in mind that the magnetic line may be due to magnetic slates and the iron formation may be nonmagnetic. A series of holes to ledge across and for some distance north and south of one of the magnetic lines would determine the character of the formation causing the less definite attractions. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in chapter VI, Bulletin XLIV of this Survey should be carefully studied.


36.2
37.6
70.54
30.4
67.87
62.62
68.53
5
3
1
40.27
CLASS C2 LANDS
CLASS C1 LANDS
7
9
11
Tupper Creek
CLASS C1 LANDS
39.73
17
15
13
Thornapple River
39.30
CLASS C1 LANDS
19
21
23
CLASS C1 LANDS
29
27
25
CLASS C2 LANDS
39.51
31
33
35

37-5W

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 37 N., R. 5 W.

Survey made in August and September, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

R. N. HUNT, Chief of Party

C. W. HONESS, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

TOWNSHIP 38N.—RANGE 1E.

SURFACE FEATURES

Nearly the whole township has the low relief of ground moraine. See profiles. Fully one-third of the area is swamp; the remaining two-thirds is brule. Though the topography of the ground moraine is low in relief the northern third has less swamp and slightly greater relief. In the northeast are many small isolated ridges rising about 20 feet above the swamps or stretches of brule.

Squaw Creek from section 21 south flows through the ground moraine in a valley much too large for a stream of its size, in many places having a valley one-half mile across. The floor of its valley is flat and swampy, the margins are definite being marked by abrupt slopes from the higher ground moraine. This valley probably carried the drainage from the retreating glacier. In the western part of section 32 and the southeastern third of section 31 is an outwash plain, in general level but in places dissected by streams tributary to Squaw Creek.

In the northern part of sections 5 and 6, is the southern extension of the kettle moraine of T. 39N.—R. 1E. Entering the township in section 34 and extending northeast through the northwest corner of section 35, the southern half of section 26, and for a half mile into section 25 is a northward extension of the heavy terminal moraine belt of the northern part of T. 37N.—R. 1E. Southwest of the lakes in section 34, it maintains the knob and kettle topography which it has in the township south. Near Dardis, Bass, and Little Dardis Lakes the knobs and sags give place to depressions separated by elevations rising no higher than the level of the sandy flat lying between these lakes and the Big Elk River. The lakes occupy such depressions. In the south of section 35 is a small area of terminal moraine characterized by knobs and kettles, with a relief of 30 to 40 feet. In the central part of section 36 is a small area of terminal moraine having steep sloped knobs and ridges.

The materials of the ground and terminal moraines are largely sand, with some gravel and numerous bowlders. In the areas of outwash the materials are largely sand with some gravel.

In the NE¼ of the SW¼ of section 35, the depth of surface as shown by drilling, page 182, is 21–33 feet. Drilling in section 31, T. 38N.—R. 2E. shows drift varying in thickness from 17–45 feet, and averaging 35 feet. Rock outcrops in section 13 of this township, section 3 of the township south, and in section 34 of the township north. In the eastern half of the township the drift probably averages less than 50 feet in thickness. Little is known regarding the thickness of drift in the western half, but it probably averages 75 feet or more.

The Big Elk road across the southeast corner and the north-south road parallel to the Soo railroad are good roads. Along these are nearly all the farms. There is a tote road along Squaw Creek, but this is in bad condition.

There is no timber in this township.

GENERAL GEOLOGY

About one-fourth mile west of the SE corner of section 13 is an exposure of medium grained granite, consisting of orthoclase feldspar, quartz, and biotite. The granite is intruded by several pegmatite dikes, varying from a few inches to a foot in thickness. The drilling in section 35 was done in 1917 by the Adbar Exploration Company under the direction of W. G. Pearsall.

Hole No. 1.

0–30′	Surface.
30–77′	Diorite.

Hole No. 2.

0–21′	Surface.
21–26′	Diorite.

Hole No. 3.

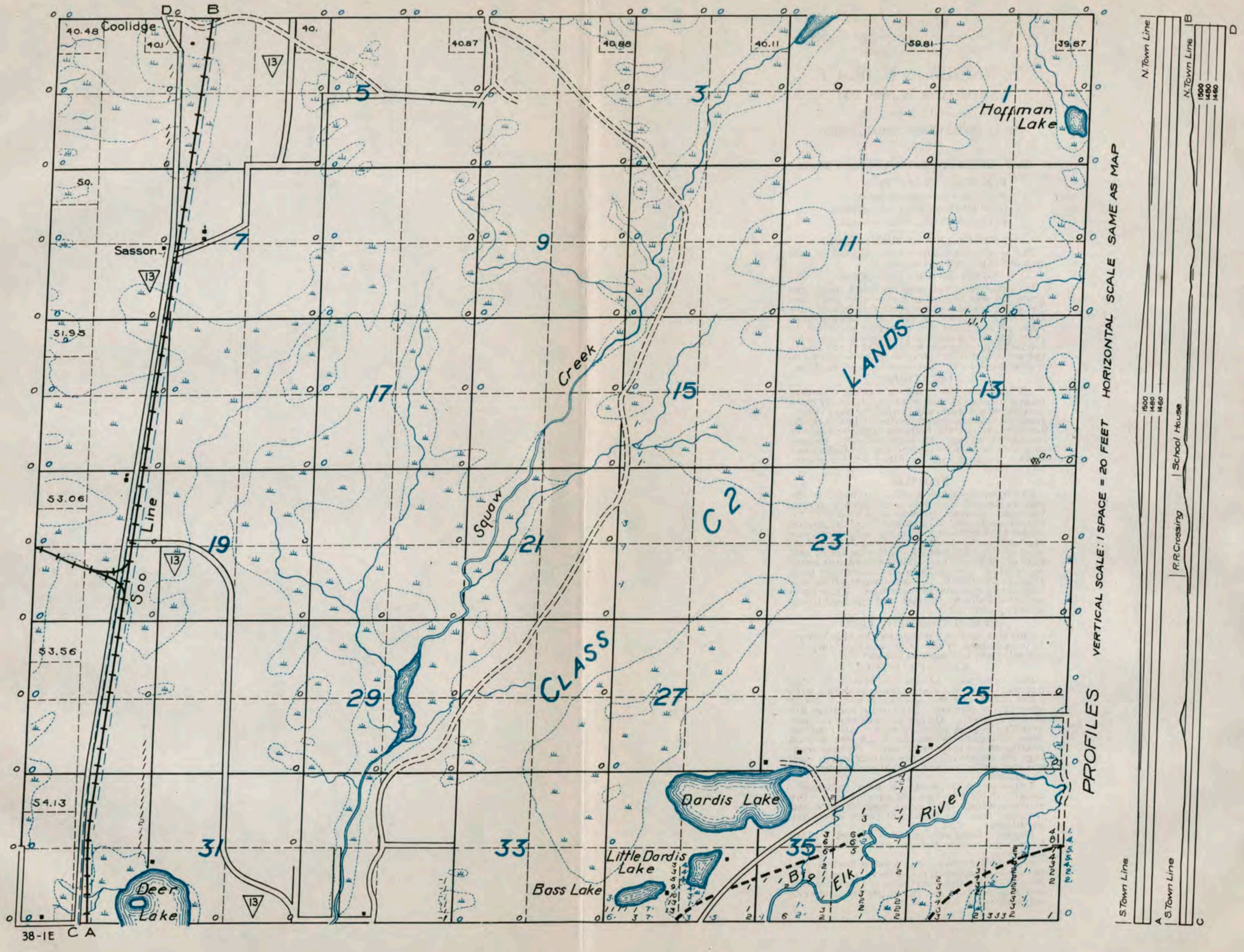
0–26′	Surface.
26–50′	Diorite.

Hole No. 4.

0–27′	Surface.
27–32′	Finely banded hornblende schist, banding dips 70°.
32–37′	Diorite.
37–42′	Hornblende schist. Dip of schistosity 85°.
42–52′	Diorite.

Hole No. 5.

0–30′	Surface.
30–40′	Hornblende schist.
40–45′	Diorite.
45–50′	Hornblende schist.
50–55′	Diorite.


Coolidge
Sasson
Soo Line
Squaw Creek
CLASS C2 LANDS
Hoffman Lake
Dardis Lake
Little Dardis Lake
Bass Lake
Deer Lake
Big Elk River
38-1E
VERTICAL SCALE: 1 SPACE = 20 FEET   HORIZONTAL SCALE SAME AS MAP
PROFILES
N. Town Line
S. Town Line
School House
R.R. Crossing

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 38 N., R. 1 E.

Survey made in June, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

R. N. HUNT, Chief of Party
M. K. DAVIS, Asst. Geologist
G. M. SCHWARTZ, Asst. Geologist
F. L. CONOVER, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

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Hole No. 6.
- 0–33′ Surface.
- 33–40′ (Hornblende schist intruded by granite) ?

Hole No. 7.
- 0–27′ Surface.
- 27–42′ Diorite.
- 42–47′ This footage shows quartzite.

The diorite is in all cases a medium grained gneissic diorite. The hornblende schist in hole No. 4 is probably sedimentary. If so the diorite is intrusive into the hornblende schist. The hornblende schist in the other holes may be merely a more schistose phase of the diorite. Drilling in section 31, T. 38N.—R. 2E. shows that the magnetic line is due to magnetitic hornblende schist. Since granite outcrops in the township east and west of this one, and the magnetic readings are normal, it is believed that the remainder of the township is underlain by granite.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in chapter IV. A fairly well defined magnetic line crosses section 36, and has with its extensions in T. 37N.—R. 1E. and T. 38N.—R. 2E. a total length of about three miles. A second line parallel to this, crossing sections 34 and 35, and continuing in T. 37N.—R. 1E., has a total length of two and one-half miles. Drilling in section 35, T. 38N.—R. 1E., page 182, 31, 38N.—2E., page 122, shows that these lines are due to hornblende schist. Over the remainder of the township the magnetic readings are nearly all normal, and this area is probably underlain by granite.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. All lands are placed in Class C2. Though the greater part of the township is probably underlain by granite, those lands are not placed in Class D, since definite information is lacking upon which such classification could be based.

EXPLORATION

No further exploration is warranted in view of the results already available from drilling these lines.

TOWNSHIP 38N.—RANGE 1W.

SURFACE FEATURES

The southern third of the township is extremely level plain with slight southward slope. See profile A–B. The well records indicate that this is an outwash plain covered with a thin veneer of till probably by a re-advance of the ice. To the north of this plain is a belt of terminal moraine extending across the central part of the township. The greater part of sections 1 to 6 is occupied by terminal moraine. These belts are characterized by NE–SW ridges and by knobs and kettles. The local relief is not more than 50 feet and probably averages less than 20 feet. Between the terminal moraines is flat to gently undulating ground moraine.

The materials of the terminal moraines are largely sand with much gravel, some silt and numerous bowlders. In the more level areas the materials are largely sand and gravel covered with a thin veneer of silt and bowlders.

The Lugerville-Phillips roads are fairly good. Along these roads are a number of settlers, who are developing good farms.

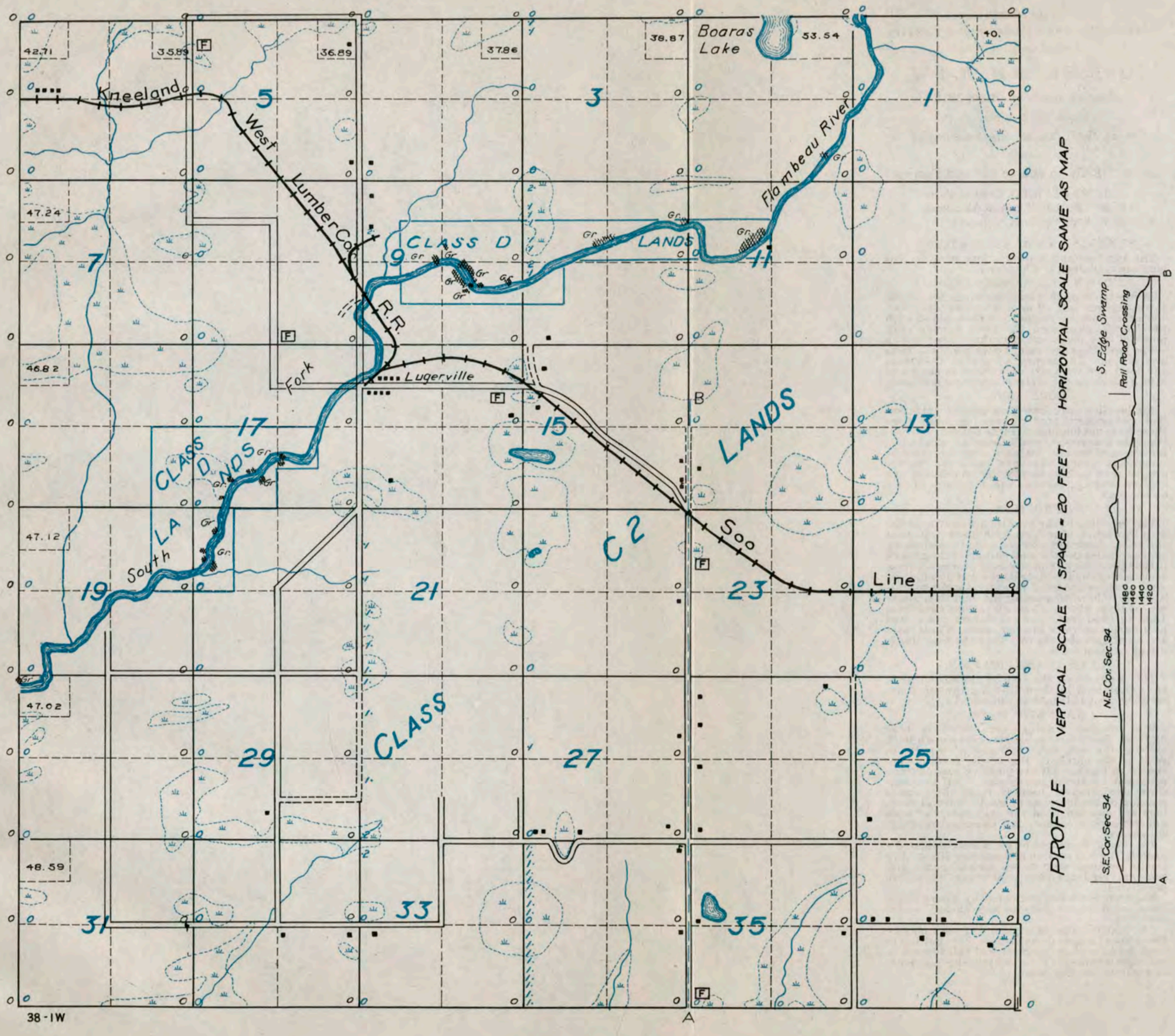
Hemlock and hardwood are found in the W½ of section 18, NW¼ section 19, N½ section 4, NW¼ section 3, W½ section 5, E½ section 8. Good cedar is found in section 14. The remainder of the township is all cut over and burned over land grown up to poplar and young hardwood.

The thickness of the drift in the areas of terminal moraine probably averages 100 feet. Outcrops are numerous along the Flambeau River and it is likely that the drift cover in the more level areas averages less than 75 feet in thickness.

GENERAL GEOLOGY

"At the center of the SE¼ of the SE¼ of section 2 there is on the north bank of the stream a low exposure of granite. The rock is medium grained, but presents considerable variation in texture and color."[1] Northwest of the center of section 11 on the north bank of the river is an exposure of medium grained pink granite. About one-fourth mile north of the east ¼ corner of section 10 is an outcrop of gray granite. North of the center of section 10 on the north bank of the river is an exposure 30 feet in width, extend-

[1] F. H. King, Geology of Wisconsin, Vol. IV, p. 600.



42.71
35.89
36.89
37.86
38.87
Boaras Lake
53.54
40.
Kneeland
5
3
1
West Lumber Co. R.R.
Flambeau River
47.24
7
9
CLASS D LANDS
11
46.82
Fork
Lugerville
B
15
13
LANDS
17
CLASS D LANDS
47.12
C2
Soo Line
South
19
21
23
47.02
CLASS
29
27
25
48.59
31
33
35
38-1W
A
PROFILE
VERTICAL SCALE 1 SPACE = 20 FEET
HORIZONTAL SCALE SAME AS MAP
S. Edge Swamp
Rail Road Crossing
N.E. Cor. Sec. 34
S.E. Cor. Sec 34
1480
1460
1440
1420

WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY
E. F. BEAN, DIRECTOR

TOWNSHIP 38 N., R. 1 W.

Survey made in June, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

H. D. WAKEFIELD, Chief of Party
E. A. KRONQUIST, Asst. Geologist
R. W. BROWN, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

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PROFILES.

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LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

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Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

ing for 700 feet along the river. This exposure is for the most part a medium grained pink granite, though there are coarser grained phases. About 250 paces NW of the E¼ corner of section 9 is a small outcrop of granite porphyry. South of the center of section 9 is Rocky Carry Rapids, caused by granite in place and by bowlders which apparently have not moved far from ledge. The granite is pink, coarse grained, with feldspar predominating. In places the granite is gneissoid, in others porphyritic. Near the center of section 17 is an outcrop of medium grained, pink granite, thickly flecked with biotite. Orthoclase is the most important mineral constituent. Along the river in the SW¼ of the SW¼ and the NW¼ of section 20 are numerous small outcrops of granite very similar in character to the last described. North of the river about 50 paces south of the NW corner of section 30 is a small outcrop of medium grained red granite. From the above description it may be seen that the granite is quite uniformly a medium grained pink granite. The variations, gneiss, mica schist, and porphyry are such as may be expected in any granite mass. The numerous outcrops, the great abundance of large bowlders in the river, and the presence of large numbers of granite bowlders in the drift make it probable that this entire township is underlain by granite.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in chapter IV. The dip readings are normal. There are a few local variations of the dial, but most of the readings are normal.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. All lands in the immediate vicinity of the granite outcrops are placed in Class D. All other lands are placed in Class C2, though believed to be underlain by granite. Since evidence of underlying granite is not positive, the D classification is not employed.

EXPLORATION

Exploration is not recommended since all the known evidence indicates that the area is underlain by granite.

TOWNSHIP 38N.—RANGE 2W.

SURFACE FEATURES

The greater part of the township is ground moraine, characterized by very gently undulating topography, broad areas of swamps, drained by sluggish streams, and shallow swampy lakes. A belt of terminal moraine crosses the northwest corner of section 6. Long Lake lies in this belt of knob and kettle topography. The relief is about 50 feet. A second belt of terminal enters section 4 from the north, extends into section 5 and 8 and terminates in section 7, occupying the eastern half of that section. The characteristic feature of this belt is the knob and kettle topography. The local relief is from 20 to 40 feet. A third belt having an average width of one-half mile enters the southeast corner of section 1, extends through section 11 and ends in the northeast of section 15. This has steep sloped high hills and numerous knobs and kettles. The average relief is 40 feet. Another belt of terminal enters in section 13, crosses section 14 and ends in the northeast of section 22. This belt has knob and kettle topography, rising abruptly 50 to 60 feet from the ground moraine to the south and sloping more gently to the north. The largest area of terminal moraine occupies the whole of sections 35 and 36, nearly all of section 25, extends westward through the south central parts of sections 34 and 33 and crosses the southeast of section 32. This area is characterized by knobs and kettles and east-west ridges. It rises to a height of at least 60 feet above the river, and near the east ¼ corner of section 33, 80 feet above the swamp to the north. King estimates the ridge west of the Flambeau in section 34 to rise 100 feet above the river.

The materials of the ground moraine are sand and silt with some bowlders. The materials of the terminal moraine are largely sand and gravel, with some silt and numerous bowlders.

There is but one settler in the township, but the soil is such that with good roads the higher ground should be excellent for farms. The only road across the township from north to south is an old tote road unfit for travel except in winter.

All the township except the swamps and section 30, 31, 34, 35, and 36, is covered with a good stand of hemlock and hardwood. The swamps are largely muskeg or young tamarack.

Since outcrops occur along the Flambeau and the extreme relief is not much over 100 feet, it is likely that the average depth of drift is less than 75 feet.

GENERAL GEOLOGY

Along the river in section 25 and 26 are numerous outcrops, and numerous angular bowlders of pink granite, very similar in character to that described in T. 38N.—R. 1W. The southeastern corner of the township is probably underlain by granite. The northwest ¼ of section 6 is possibly underlain by iron formation. Since there are no rock outcrops in the remainder of the township, geological inferences must be based on the results of magnetic work. As the readings are normal, the area is most likely underlain by granite.

MAGNETIC OBSERVATIONS

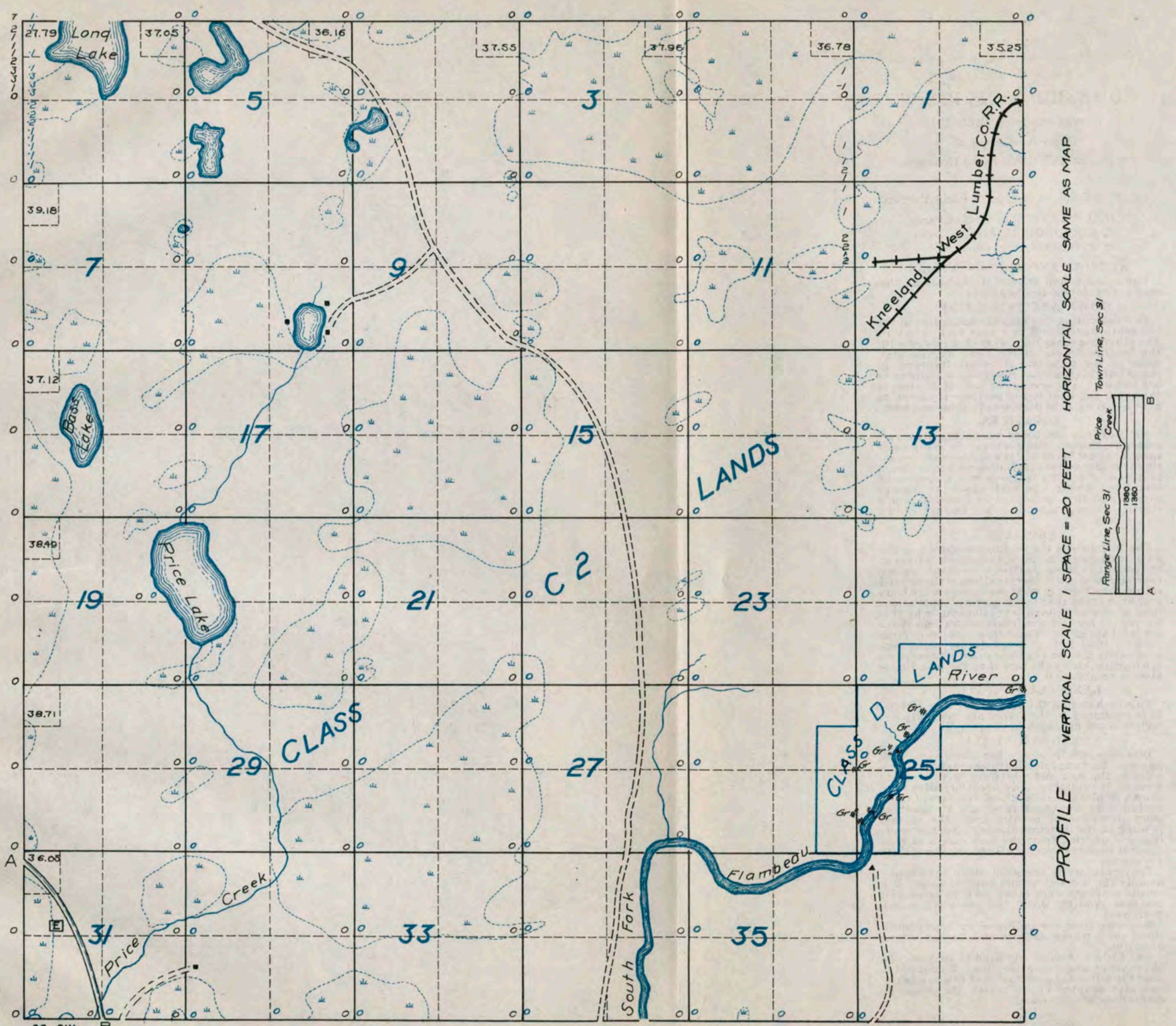
A general discussion of magnetic observations and their significance is given in Chapter IV. Along the west line of section 6 are westward variations of from 1°–3°. The dip readings range from 1°–7°. These attractions are due to the formation which causes the magnetic line just north of the northwest corner of section 6, see page 282, Bulletin XLIV of this Survey. This line is possibly due to Huronian iron formation. On the east lines of sections 2 and 11 are abnormal dip readings. Elsewhere in the township the magnetic readings are normal.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in the work is given on page 112. Lands in the vicinity of granite outcrops are placed in Class D. All other lands are placed in Class C2.

EXPLORATION

The only place in this township where exploration can be considered is in the northwest of section 6. If exploration along the magnetic line in T. 38N.—R. 3W. or in T. 39N.—R. 2W. results favorably, some exploration in the northwest ¼ of section 6 is recommended. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geological information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussiin of this subject in Chapter VI, Bulletin XLIV of this Survey should be carefully studied.



Long Lake
27.79
37.05
36.16
37.55
37.96
36.78
35.25
39.18
37.12
38.49
38.71
36.05
5
3
1
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
Bass Lake
Price Lake
Price Creek
South Fork
Flambeau River
Kneeland West Lumber Co. R.R.
CLASS C2 LANDS
CLASS D LANDS
Gr
E
A
B
38-2W
PROFILE
VERTICAL SCALE 1 SPACE = 20 FEET
HORIZONTAL SCALE SAME AS MAP
Range Line, Sec 31
Price Creek
Town Line, Sec 31
1380
1360

WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY
E. F. BEAN, DIRECTOR

TOWNSHIP 38 N., R. 2 W.

Survey made in June, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

H. D. WAKEFIELD, Chief of Party
E. A. KRONQUIST, Asst. Geologist
R. W. BROWN, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

TOWNSHIP 38N.—RANGE 3W.

SURFACE FEATURES

The most striking feature of this township is the parallel arrangement of its drainage and relief features. Extending diagonally across the township is a chain of lakes connected by swamps. It seems quite probable this represents the preglacial valley of the Flambeau River. Parallel to these lakes and about two miles westward is the Flambeau River. Between these drainage lines is a belt of strong terminal moraine, characterized by NE–SW ridges, having a local relief as great as 100 feet (profile A-B) and by knobs and kettles. East and west of the terminal moraine are strips of outwash. The Flambeau River flows through the western strip about 125 feet below the moraine to the east (Profile A–B). This plain is very level, with a few pits occupied by swamps. The eastern outwash plain has been modified to some extent by a re-advance of the ice, and is occupied by a chain of lakes connected by marshes. The ground moraine in the southeast and northwest parts of the township is characterized by gently undulating topography and numerous broad swamps.

The materials of the terminal moraine and outwash plains are predominantly sand; with some gravel and few bowlders. The materials of the ground moraine are sand and silt and numerous bowlders.

The thickness of the drift probably averages 100 feet. Since there are no rock outcrops nor deep wells this estimate is based upon the fact that the extreme relief shown by the profile is 125 feet, and a local relief of 100 feet in the terminal moraine has been noted.

On Connor's Lake is a summer home and a summer resort. Outside of a few cabins on the Flambeau, there is no settlement in the township. A poor road has been built from Merrill's Resort to Connor's Lake. A section line road has been brushed out along the south line of sections 7 and 8. This will eventually be a part of a Phillips-Winter road.

Hemlock and hardwood cover the entire township except for the swamps and a small area of brule along the Flambeau in the northern part of the township. There is tamarack and spruce with some cedar in the swamps.

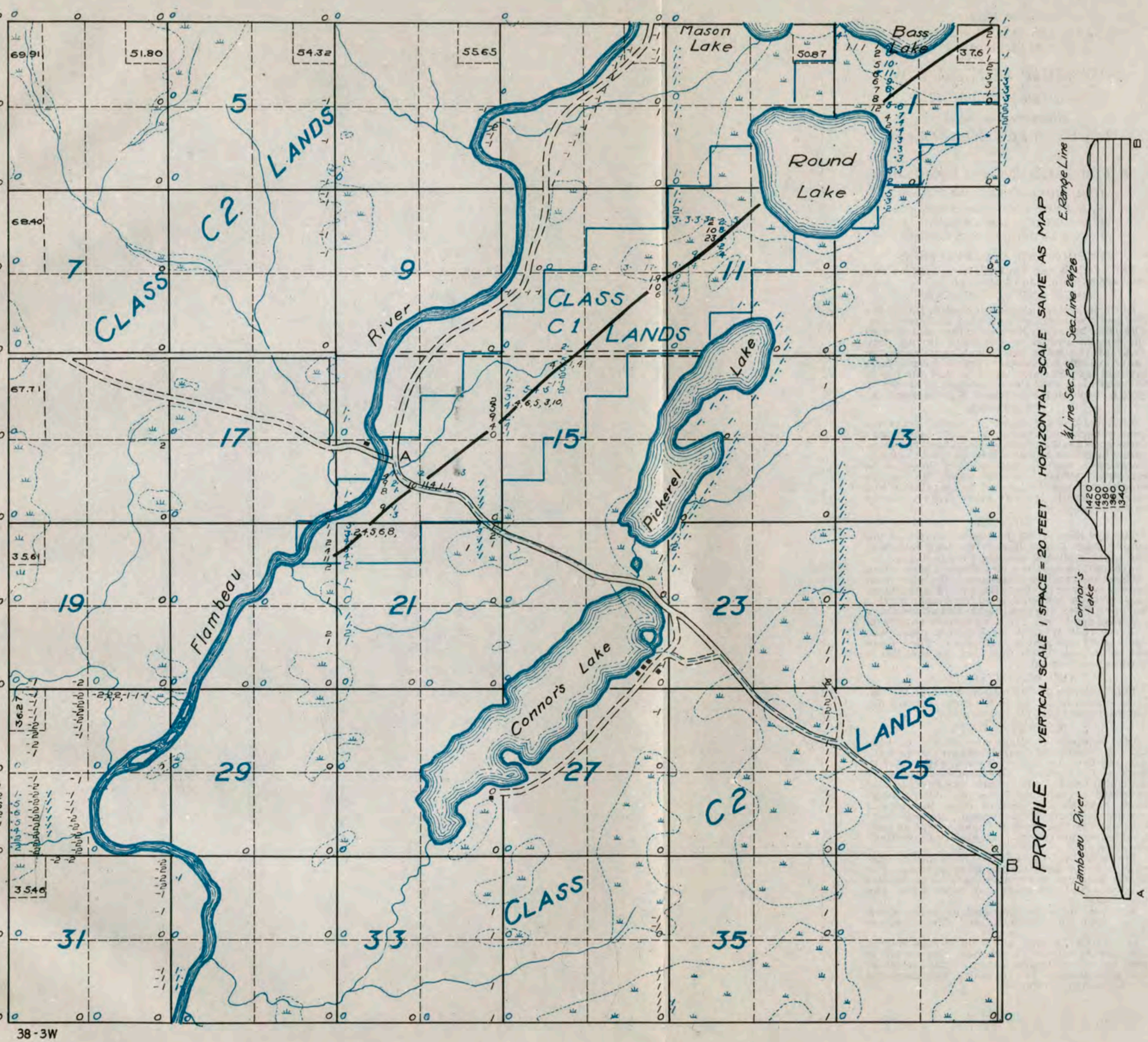
GENERAL GEOLOGY

There are no rock outcrops in this township nor in those adjoining on the north and west. Granite outcrops along the Flambeau in T. 38N.—R. 2W. and T. 37N.—R. 3W. Hence geological inferences must be based largely on the results of magnetic work. The character of the line of magnetic attraction has suggested that the northwestern half and possibly the entire township is underlain by magnetic slates, schists, or iron formation. However, in T. 39N.—R. 1W. the magnetic area parallel to this was drilled and although sediments were disclosed they were not indicative of iron formation and the attraction was caused by a diorite intrusive probably a sill parallel to the formation.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in Chapter IV. A magnetic line extends from the northeast corner of section 1 to near the southwest corner of section 16. This line is possibly due to a sedimentary formation or to a schist since the attraction is roughly uniform and the belt of attraction is of uniform width. This line continues for over two miles in T. 39N.—R. 2W. In that township are other magnetic lines parallel to this one, one of which cuts into T. 39N.—R. 1W. and was drilled, disclosing a diorite intrusive. More detailed work in this township would also show other lines parallel to the one shown. This magnetic line may be interpreted as the surface expression of a more magnetic slate, iron formation, or schist. The areas to the north and south may be underlain by slightly magnetic or non-magnetic formations. It will be noted that in township 39—2W. and the western part of 39—1W. the Flambeau River flows in a course nearly parallel to the magnetic belts, that in this township the strong magnetic line is roughly parallel to the long chain of lakes and swamps. It seems quite likely that the preglacial course of the Flambeau may have been along the strike of a softer sedimentary formation such as a slate, or limestone. This idea is strengthened by the results of drilling in 39—1W. p. (124) where dolomite was found in two holes on the south bank of the river at a depth of but 75 and 83 feet.

The negative readings in sections 30 and 31 may be due to an intrusion of igneous rock cutting the country rock. Outside the



Mason Lake
Bass Lake
Round Lake
Pickerel Lake
Connor's Lake
Flambeau River
CLASS C2 LANDS
CLASS C1 LANDS
CLASS C2 LANDS
69.91
51.80
54.32
55.65
50.87
37.6
68.40
67.71
35.61
36.27
35.46
1
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
A
B
38-3W
PROFILE
VERTICAL SCALE 1 SPACE = 20 FEET HORIZONTAL SCALE SAME AS MAP
E. Range Line
Sec. Line 26/25
½ Line Sec. 26
Connor's Lake
Flambeau River
1420
1400
1380
1360
1340

WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY
E. F. BEAN, DIRECTOR

TOWNSHIP 38 N., R. 3 W.

Survey made in July, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

H. N. EIDEMILLER, Chief of Party
E. A. KRONQUIST, Asst. Geologist
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LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

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Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

areas described there are scattered light dip readings varying from 2° more than normal to 2° less than normal.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. Lands along the magnetic line are placed in Class C1. All other lands are placed in Class C2.

EXPLORATION

Lands along the magnetic line are considered a favorable place for a limited amount of exploration although the drilling in T. 39N.—R. 1W. disclosed diorites as the cause of attraction. Nevertheless sediments were exposed, and a small amount of drilling would suffice to determine the character of the magnetic formation here. In exploration it should be borne in mind that the magnetic line may be due to magnetic slates or schists and that the iron formation may be non-magnetic. A series of holes to ledge across and for some distance north and south of the magnetic line would determine the character of the formation causing the less definite attractions. In case of successful exploration along this magnetic belt either in 39—1 or 2W., there would, of course, be no hesitancy about exploring along the line in this township. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic formation given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in Chapter VI, Bulletin XLIV of this Survey should be carefully studied.

TOWNSHIP 41N.—RANGE 3W.

SURFACE FEATURES

A belt of terminal moraine averaging nearly two miles in width extends from sections 12 and 13 to the southwest corner of the township. The most striking topographic features of this belt are the ridges trending in general NE–SW. Some of these ridges are long and narrow, others short and irregular in outline, but the greater number are wide, irregular, usually gently sloping hills that rise from 20–70 feet above the river or swamp lands. The steepest slopes are seen along the Chippewa River where it flows thru this terminal moraine. In many cases the long valley-like depressions between ridges are occupied by swamps. There are many kettles on the larger ridges. The profile shows the topography of the terminal moraine. The remainder of the township is gently undulating ground moraine, fully one-half of which is swampy.

The materials of the ground moraine are sand and silt with numerous bowlders. In the terminal moraine there is a higher proportion of sand and gravel.

The thickness of the drift is not definitely known except near the outcrop in section 18. It is believed that in the ground moraine areas the drift cover does not average over 50 feet in thickness. This is indicated by the numerous angular bowlders and the fact that outcrops occur at swamp level in this township and in the one west. In the terminal moraine the thickness is at least 70 feet, since the river is in drift and some of the hills rise at least 70 feet above the river. In the township south ten drill holes, p. 134, show drift averaging 186 feet in thickness.

The secondary road shown on the map is an abandoned railroad grade. With a little repair this could be made an excellent road. There are no settlers in the township.

The land south of the river was formerly covered with hardwood and hemlock. Nearly all this area has been cut over and burned. North of the river and parallel with it, there is a belt of hemlock and hardwood about one mile in width, extending from the east side of section 15 to the west side of section 30. On the west range line in sections 6, 7, and 18 there is another belt of hardwood one-half mile wide and one and one-half miles long. In section three there are three forties of hemlock. The rest of the township north of the river has poplar, brule, on the uplands, and cedar and tamarack in the swamps.

GENERAL GEOLOGY

There is an exposure of granite gneiss near the southeast corner of section 18. The minerals are quartz, feldspar and biotite mica arranged in bands trending E–W. The gneiss is cut by two pegmatite dikes. Though this gneiss is not magnetic in the hand specimen, it is associated with a magnetic formation, the strike of which is shown by the magnetic line. The magnetic readings suggest in their uniformity and regularity that this magnetic formation is sedimentary rather than igneous in origin. The magnetic line in sections 7, 8 and 17 may also be due to a sedimentary formation. The southwestern part of the township is therefore mapped as Huronian and may be underlain by schist, slate, dolomite, quartzite, or iron formation. Since neither abnormal magnetic attractions nor outcrops occur in the northeastern part of the township, a definite statement regarding the character of the underlying rock can not be made. It is probably underlain by granite.

MAGNETIC OBSERVATIONS

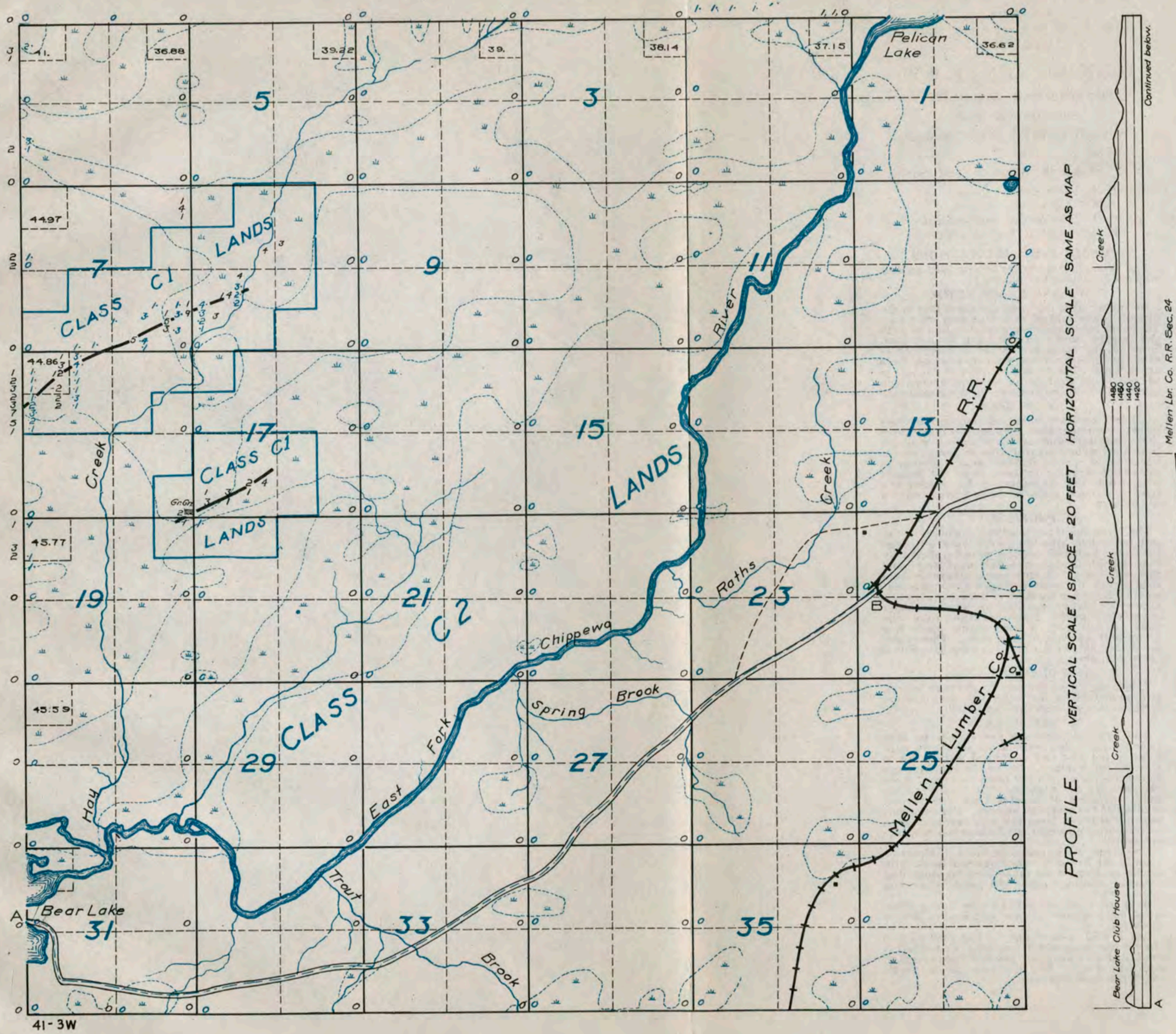
A general discussion of magnetic observations and their significance is given in Chapter IV. Except along the two lines shown, all magnetic readings are normal. The magnetic line beginning near the center of section 8, trends S. 30°W. for two and one-half miles. The maximum dip readings range from 3°–14°. The dial readings range from 4°W. to 4°E. This line is believed to be due to a magnetic schist, slate, or iron formation rather than an intrusive, because of the lightness and uniformity of the attractions, and the extent of this line and its parallelism with other lines. The magnetic line in the southwest of section 17 is similar in trend to the one a mile north. The attractions are somewhat weaker, however. It is possible that this magnetic line is due to a sedimentary formation deposited upon the gneiss, although magnetic bands within the gneiss, original or anamorphic are well within the range of possibility.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. Lands along the magnetic lines are placed in Class C1. Since the gneiss outcrop is small and its extent is not known, a separate classification of this is not made. The remainder of the township is classed as C2.

EXPLORATION

A moderate amount of exploration along the northern magnetic line is justified on the basis of the magnetic attractions. In exploration it should be borne in mind that the magnetic line may be due to magnetic slates and that the iron formation may be nonmagnetic. A series of holes to ledge across and for some distance north and south of one of these magnetic lines would determine the character of the formation causing the magnetic line as well as that of the formation causing the less definite attractions. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic formation given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploring therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in Chapter VI, Bulletin XLIV of this Survey should be carefully studied.


Pelican Lake
Bear Lake
5
3
1
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
CLASS C1 LANDS
CLASS C1 LANDS
CLASS C2 LANDS
Creek
Hay Creek
River
Creek
Raths Creek
Chippewa
East Fork
Spring Brook
Trout Brook
Mellen Lumber Co. R.R.
A
B
36.88
39.22
39.
38.14
37.15
36.62
44.97
44.86
45.77
45.59
41-3W
PROFILE
VERTICAL SCALE 1 SPACE = 20 FEET
HORIZONTAL SCALE SAME AS MAP
Bear Lake Club House
Creek
Mellen Lbr. Co. R.R. Sec. 24
1480
1460
1440
1420
Continued from above B
Continued below.

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 41 N., R. 3 W.

Survey made in August, 1915

Under the direction of

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AND

E. F. BEAN, in charge of Field Parties

R. N. HUNT, Chief of Party

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F. L. CONOVER, Asst. Geologist

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LOCATIONS.

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TOWNSHIP 41N.—RANGE 4W.

SURFACE FEATURES

Most of this township has the gently undulating topography characteristic of ground moraine, but a large part of the area is a swamp. There are three belts of terminal moraine which are conspicuous largely because their topography is in such strong contrast with that of the nearly level ground moraine. One of these belts, ½ to 1½ miles in width, crosses the southeastern corner of the township west of Bear Lake. A second belt extends with some breaks from the central part of section 13 through sections 30, 31, and 32. A third belt covers parts of sections 2, 3, 4, 5, 6, 7, 8, and 9. The terminal moraine is characterized by long narrow ridges which usually extend from northeast to southwest, and by wide shallow meadow-like depressions.

The materials of the ground moraine are largely sand, with some silt and in places numerous bowlders. The material of the terminal moraine are sand and gravel with numerous bowlders.

The thickness of the drift is not definitely known except near the outcrop in section 14. It is believed that in the ground moraine areas the drift cover does not exceed 50 feet in thickness. This is indicated by the numerous angular bowlders and the fact that outcrops occur at swamp level in this township and in the one east, and along the river in section 4 of the township south. The average thickness of drift as shown by eight drill holes in the township south (p. 137) is 98 feet.

There are no roads in the township. The cottages on the east shore of Bear Lake are reached by road from the east or by the Chippewa River.

In the west half of section 30 and in the south half of section 19 there is hardwood and hemlock. North of the Chippewa is a belt of hardwood and hemlock averaging ¾ of a mile in width, extending from the center of section 13 thru sections 23, 26, 27, and 33. In the swamp land there is much tamarack.

GENERAL GEOLOGY

Several low outcrops of granite occur near the center of the NE¼ of Sec. 14. The most typical phase of these outcrops is a rather coarse grained pink granite. Another phase is a fine grained granite gneiss. Both granite and gneiss are cut by pegmatite dikes. The magnetic lines are believed to be due to a magnetic schist, iron formation, or slate. Since neither abnormal magnetic readings nor outcrops occur over the remainder of the township, a definite statement regarding the character of the underlying rock can not be made. On the basis of the small outcrops and abundant bowlders the extreme northern part is mapped as granite and the southern part as Huronian. It should be noted that in this area traverses were made only on the sections lines. More detailed work would probably locate more outcrops and make a more accurate geological map possible.

MAGNETIC OBSERVATIONS

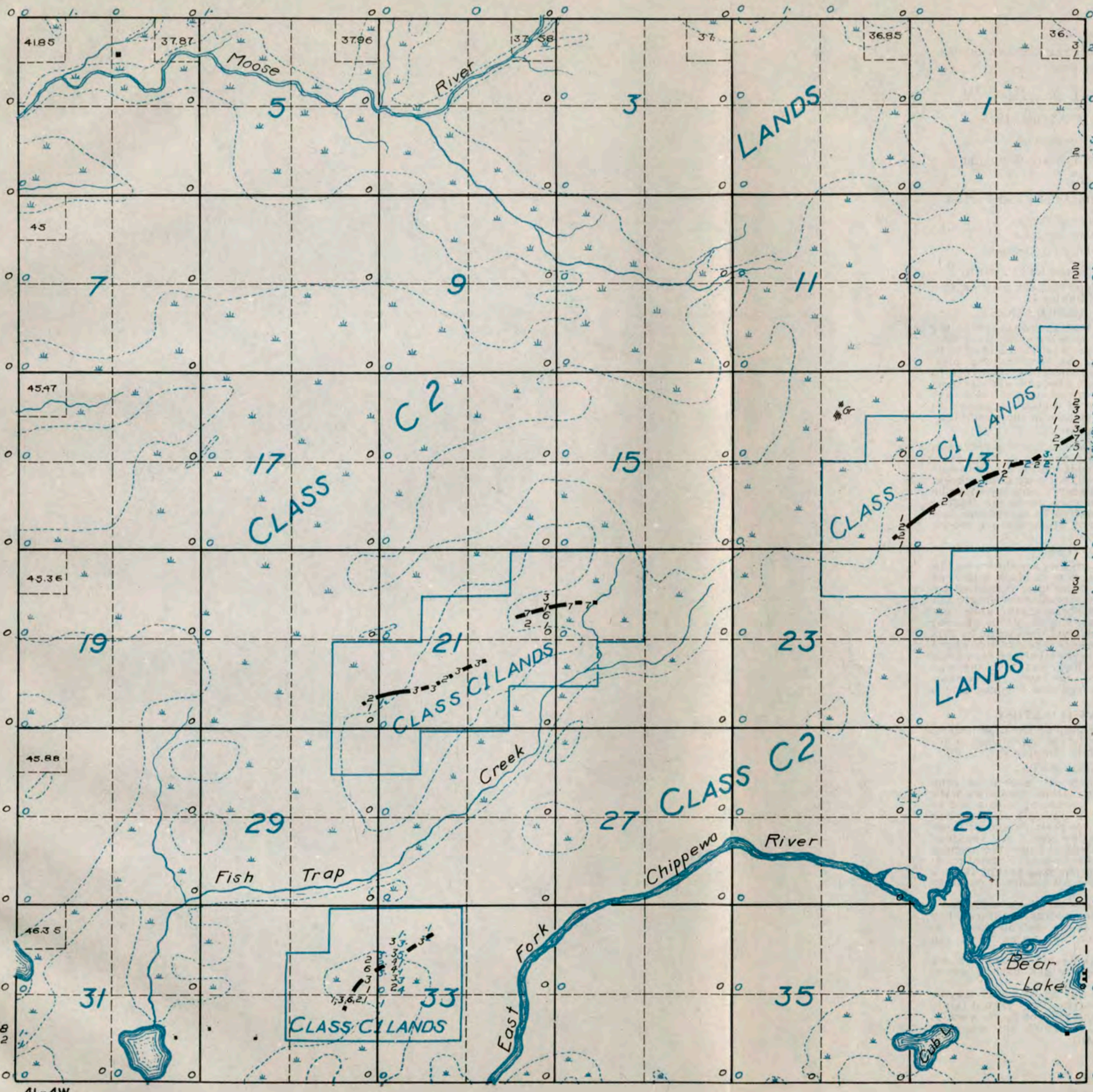
A general discussion of magnetic observations and their significance is given in Chapter IV. The magnetic line in section 13 has with its extension in T. 41—R. 3W., a total length of nearly three miles. There are two shorter lines in section 21. A fourth line was found in sections 32 and 33. These magnetic lines are believed to be due to magnetitic schists, iron formation, or slate rather than to intrusive rocks because of the lightness of the at-adjoining are parallel. A folded and eroded slightly magnetic formation made up of slate, schist, or iron formation or magnetic formation made up of slate, schist, or iron formation or of any combination of these would produce attraction similar to these. The broad areas of non-magnetic territory may be due to granite or to non-magnetic schist, slate, or iron formation.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. Lands along the magnetic lines are placed in Class C1, since they are crossed by magnetic lines showing good characteristics. All other lands are placed in Class C2.

EXPLORATION

A moderate amount of exploration along the magnetic lines is justified on the basis of the magnetic attractions. In exploration it should be borne in mind that the magnetic line may be due to magnetic slates and that the iron formation may be non-magnetic.


Moose River
Chippewa River
East Fork
Fish Trap Creek
Bear Lake
Cub L.
CLASS C2
CLASS C1 LANDS
CLASS C1 LANDS
CLASS C1 LANDS
CLASS C2 LANDS
CLASS C2
LANDS
41.85
37.87
37.96
37.58
37.
36.85
36.
45
45.47
45.36
45.88
46.35
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
41-4W

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 41 N., R. 4 W.

Survey made in August, 1915

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A series of holes to ledge across and for some distance north and south of one of these magnetic lines would determine the character of the formation causing the magnetic line as well as that of the formations causing the less definite attractions. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration, therefore, cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in Chapter VI, Bulletin XLIV of this Survey should be carefully studied.

TOWNSHIP 41N.—RANGE 5W.

SURFACE FEATURES

A line drawn from the northwest corner of section 1 to the southeast corner of section 31, divides this township topographically into two areas. Northwest of this line is a belt of terminal moraine, to the southeast is ground moraine. The conspicuous feature of the terminal moraine is the knob and sag topography. The average local relief is about 30 feet; in sections 4 and 5 the relief reaches 50 feet, but in sections 7 and 8 it is not over 20 feet. The terminal moraine is best developed in sections 4 and 5 and near Moose Lake. West of Moose Lake there are no level places as knobs and sags occupy the whole area. Several hollows are occupied by ponds. The sides of the knobs are strewn with granite bowlders. Near the lake this irregular surface results in a much indented shore and steep sloped islands. Within this belt of terminal moraine are small areas of ground moraine. The southeast half of the township is ground moraine. The average relief is not more than 20 feet, the slopes are gentle and knobs are lacking. Very shallow saucer-shaped kettles are quite numerous. These appear in the hardwoods as mucky holes either open or covered with tamarack. Within this ground moraine area, especially in sections 12 and 13 are narrow belts of terminal moraine. The range in relief is no greater than that of the ground moraine, but the slopes are much shorter and steeper, hence the apparent relief is greater. Knobs and kettles characterize these belts. Along the Big Moose River are well developed terraces sometimes as much as 15 feet high.

The materials of the ground moraine are sand and silt with numerous bowlders. The materials of the terminal moraine are sand and gravel, also with numerous bowlders.

The thickness of the drift is not known. The lack of outcrops, in spite of the fact that several large streams flow through this area, and the terminal moraine in the northwest suggest that the drift cover is probably close to 100 feet in thickness. Four drill holes in the township south, p. 141, show drift averaging 117 feet in thickness. Four drill holes in the township west, p. 141, show drift averaging 76 feet in thickness.

Except for the road to the resort on the west side of Moose Lake, there are no good roads in the township. Because of the long distance from a railroad, settlement has been slow.

The upland in the southeast quarter of the township has a fair growth of mixed hardwoods. On the south shore of Moose Lake there are a few forties of timber. In parts of sections 8, 18, and 19, a good stand of hardwood and hemlock remains. The swamps, where tree covered, are largely tamarack, with some cedar. The remaining portions of the area have been burned over repeatedly and are now grown up to poplar.

GENERAL GEOLOGY

No outcrops were found. In the Chippewa River near the west ¼ of section 7 at the head of Brown's Rapids, numerous large and very angular irregularly shaped granite gneiss bowlders were found. The number, size, angularity, and uniform type of these bowlders very strongly suggest that they have not been carried far from the parent ledge. Drilling in section 1 of the township west shows hornblende schist intruded by pink granite, and in sections 6 and 7 of the township south shows gneissic granite, p. 141. It is believed that schists or Huronian sediments underlie the southern part of this township, and that lenses of more magnetic schist, slate, or iron formation are the cause of the magnetic lines. In the absence of definite evidence the northern part has also been mapped as possible Huronian. More detailed work may show the presence of granite or gneiss in the north.

MAGNETIC OBSERVATIONS

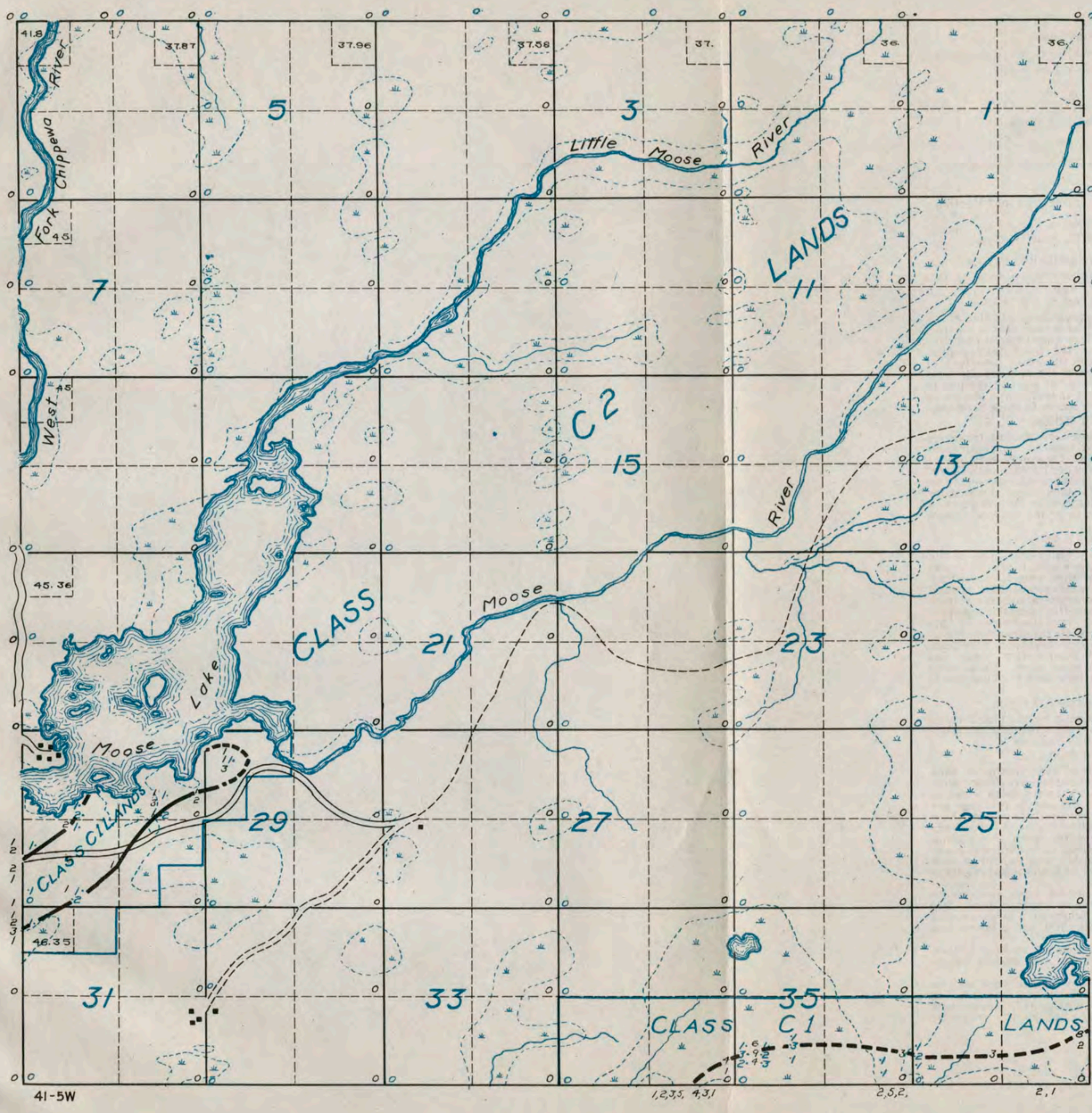
A general discussion of magnetic observations and their significance is given in chapter IV. In this township are two well defined magnetic lines. One crosses the southern part of sections 35 and 36, and leaves the township in section 34. It is believed that with careful work this line could be traced for over a mile in T. 40—R. 5W. The maximum dips along this line range from 1°–9°. The lines south of Moose Lake suggest a fold though the tracing of the line could not be completed because of the lake. It is believed that these lines could be followed in T. 41—R. 6W. A slightly magnetic formation such as a schist, or iron formation would produce magnetic lines similar to these.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given in page 112. Lands along the magnetic lines are placed in Class C1. All others are placed in Class C2.

EXPLORATION

On the basis of magnetic attractions, a small amount of exploration is justified. In exploration it should be borne in mind that the magnetic line may be due to magnetitic slates and that the iron formation may be non-magnetic. A series of holes to ledge across and for some distance north and south of one of the magnetic lines would determine the character of the formation causing the magnetic line as well as that of the formations causing the less definite attractions. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey, and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in chapter VI, Bulletin XLIV of this Survey should be carefully studied.



West Fork Chippewa River
Little Moose River
Moose River
Moose Lake
CLASS C2 LANDS
CLASS C1 LANDS
CLASS C1 LANDS
41.8
37.87
37.96
37.58
37.
36.
36.
45
45
45.36
46.35
1
3
5
7
11
13
15
21
23
25
27
29
31
33
35
41-5W

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 41 N., R. 5 W.

Survey made in August, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

R. N. HUNT, Chief of Party
G. M. SCHWARTZ, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township de-.ription and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

TOWNSHIP 42N.—RANGE 3W.

SURFACE FEATURES

Fully four-fifths of the township is ground moraine, a large part of which is swamp. The higher parts of the ground moraine are very gently undulating with an average relief of 5–10 feet and a maximum relief of 15–20 feet. There are two belts of terminal moraine. One belt enters the township in section 4 and leaves in section 7. In section 4 this moraine has a local relief of 65 feet. See profile. Farther southwest the relief is not more than 20 feet. The other belt which averages one-half mile in width is crescent shaped and extends through parts of sections 12, 13, 24, 23, 26, 22, 21, 20, 27, and 28. In section 12 the local relief is 40 feet and the topography is of the knob and sag type. The remainder of the belt is weak terminal characterized by knobs and kettles but low relief.

The materials of the glacial drift are predominantly sand with some silt and numerous bowlders.

The thickness of the drift is not definitely known. It is believed that outside the areas of more pronounced terminal moraine the drift does not average over 50 feet in thickness.

A good road has been constructed along the north township line, connecting this township with the nearest town, Glidden. A poor road crosses the southeast corner of the township. There is no settlement in the area.

Cedar, tamarack, and spruce are found in the swamps. On the uplands there is a fairly good stand of hardwood and hemlock. Parts of sections 13, 24, 25, 19, 20, 29, 30, 31, and 32 have been cut over, subsequently burned over and are now grown up to poplar.

GENERAL GEOLOGY

There is a small outcrop of granite 800 paces north of the southwest corner of section 31. Here bands of pegmatite a foot in thickness alternate with bands of finer grained granite. The pegmatite is composed largely of feldspar crystals up to 2 inches in length, with some sericite and a small amount of quartz. The granite is coarsely crystalline, but contains more quartz than does the pegmatite. It is believed that granite forms the country rock in this general region, since large angular bowlders similar to those found in the outcrop are strewn thickly over the ground to the southeast. The topography suggests the influence of rock thinly covered with drift, since low, broad mounds covered with large angular bowlders rise above the swamp, both to the north and east of this exposure.

One tally east of the northeast corner of section 4, on the north side of the road is a small exposure of weathered green chlorite schist. There is a possible outcrop 500 paces south and 100 paces west of the northeast corner of section 27. This consists of a small surface of granite exposed on a hill slope. Wherever outcrops were found in the townships surrounding this one, the rock is granite or granite gneiss. This makes it appear probable that this township with the exception of the northwestern part, is underlain by granite. The well defined magnetic line in sections 22, 27, and 28 would in this case be ascribed to an infolded remnant of magnetic Huronian sediments, or to schist.

MAGNETIC OBSERVATIONS

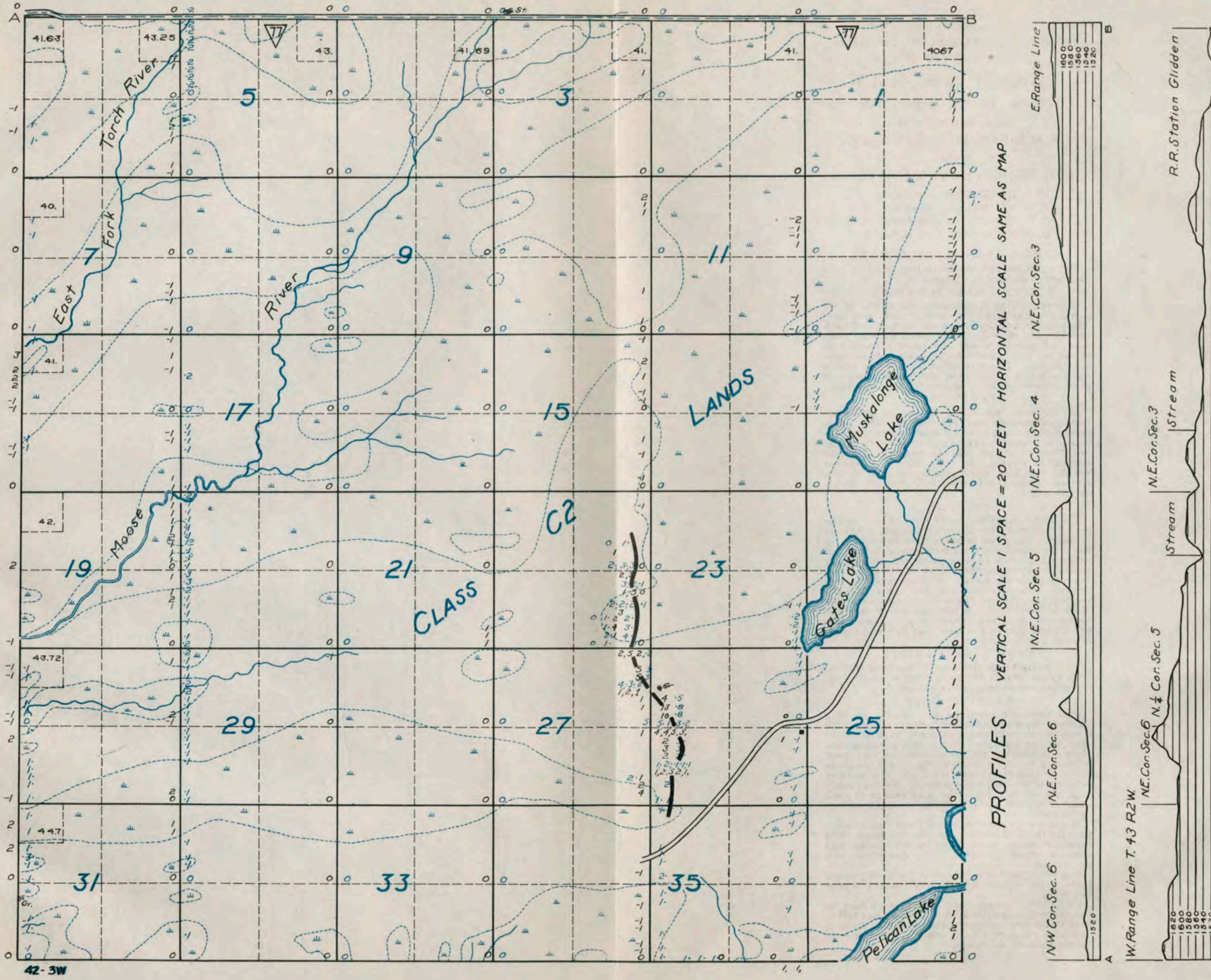
A general discussion of magnetic observations and their significance is given in chapter IV. Magnetic attractions are found over nearly all the township, but with the one above noted exception, these readings have the erratic characteristics of magnetics due to igneous rocks. A well defined line was traced in sections 22, 26 and 27. The maximum dip readings vary from 3°–13°, and the dial readings range from 5E.–8W. A slightly magnetic slate, schist, or iron formation would produce attractions similar to these.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. All lands are placed in Class C2.

EXPLORATION

A small amount of exploration along the magnetic line is justified on the basis of the magnetic attractions. In exploration it should be borne in mind that the magnetic line may be due to magnetic slates and that the iron formation may be non-magnetic. A series of holes to ledge across and for some distance east and west of this magnetic line would determine the character of the formation causing the magnetic line as well as that of the formations causing the less definite attractions. Much of the work done in exploration



A
B
5
3
1
7
9
11
17
15
13
19
21
23
29
27
25
31
33
35
East Fork Torch River
River
Moose
LANDS
C2
CLASS
Muskalonge Lake
Gates Lake
Pelican Lake
42-3W
PROFILES
VERTICAL SCALE 1 SPACE = 20 FEET HORIZONTAL SCALE SAME AS MAP
E. Range Line
N.E. Cor. Sec. 3
N.E. Cor. Sec. 4
N.E. Cor. Sec. 5
N.E. Cor. Sec. 6
NW Cor. Sec. 6
R.R. Station Glidden
Stream
W. Range Line T. 43 R2W.
N. ¼ Cor. Sec. 5

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 42 N., R. 3 W.

Survey made in August, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

W. L. DOBIE, Chief of Party
R. W. BROWN, Asst. Geologist
C. W. HONESS, Asst. Geologist
D. G. THOMPSON, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration, therefore, cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject Chapter VI, Bulletin XLIV of this Survey should be carefully studied.

TOWNSHIP 42N.—RANGE 4W.

SURFACE FEATURES

Three types of topography are found in this township,—ground moraine, terminal moraine, and outwash. The ground moraine which covers over half of the area is characterized by gently undulating or level topography, with a large amount of swamp. Over the township are numerous terminal moraine ridges, having a general trend of N. 60°E. Many of these belts are but a few tallies in width. Their length varies from a few rods to three miles. These ridges rise from 20 to 60 feet above the surrounding outwash plain or ground moraine. See profile A–B. An outwash plain covering about one-fourth the township lies in the western part of the township. This plain is nearly level, but in places there are small kettles having a depth of 5 to 10 feet. The outwash plain is distinguished from the level ground moraine by the fact that there are no bowlders in the outwash, while bowlders are numerous in the ground moraine.

The materials of the ground moraine and terminal moraine are largely sand with some silt and numerous bowlders. In the outwash areas the material is sand.

The thickness of the drift is not known since there are no wells. Ledge is exposed in sections 31 and 36. It seems likely that the average thickness of drift is not over 50 feet.

The roads in the northern part of the township are in but fair condition. The Superior and Southeastern Railway extends for three miles into this township. There is no settlement due probably to the long distance from towns.

The major portion of the uncut timber is in the northern part. Sections 1 and 2 have a good stand of hardwood and hemlock. A strip of hardwood about one fourth mile in width extends across the southern part of sections 5 and 6. Small areas occur in sections 22, 26, 32, 33, and 35. The outwash plain was originally covered with pine. Nearly all the township outside these areas and the wetter swamps has been swept by fire, and is now grown up to poplar. The timber in the swamp is cedar and tamarack, with some alder and ash.

GENERAL GEOLOGY

There is a small outcrop of granite 800 paces north of the southeast corner of section 36. Here bands of pegmatite a foot in thickness alternate with bands of fine grained granite. The pegmatite is composed largely of feldspar crystals up to 2 inches in length with some sericite and a small amount of quartz. The granite is coarsely crystalline but contains more quartz than does the pegmatite. It is believed that granite forms the country rock in this general region since large angular bowlders similar to those found in the outcrop are strewn thickly over the gound to the southeast. The topography suggests the influence of rock thinly covered with drift since low broad mounds covered with large angular bowlders rise above the swamp, both to the north and east of this exposure. 200 paces north of the southwest corner of section 31 is an outcrop of granite gneiss, extending east and west for 135 paces and having a width of about 25 paces. Large boulders of gneiss almost completely cover the ground to the east for one-fourth mile. The outcrop consists of alternating bands of light and dark materials. The lighter bands, averaging one-fourth inch in width, are continuous for long distances and have a strike of S. 83°E. and dip 80° S. They are made up of quartz and feldspar. The darker bands are made up of chlorite. Much of the chloritic material is wavy and shows the results of shearing. The lighter more resistant bands are brought into relief by weathering of the darker bands. 900 paces west of the southeast corner of section 35 there are numerous angular blocks of gneiss varying in size from 3 to 5 feet in diameter. It is likely that similar gneiss underlies this area. It is believed that the southern part of this township is underlain by granite and gneiss. The magnetic line in section 18 is probably due to magnetic schists, slates, or iron formation. The northern part of the township has been mapped as possible Huronian since no evidence is available regarding the character of the underlying rock.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in chapter IV. A well defined magnetic line extends from near the southeast corner of section 18 westward for one mile. More detailed work would probably show that this line continues for at least one and one-half miles in T. 42—R. 5W. This line is probably due to a magnetic schist, slate, or iron formation.

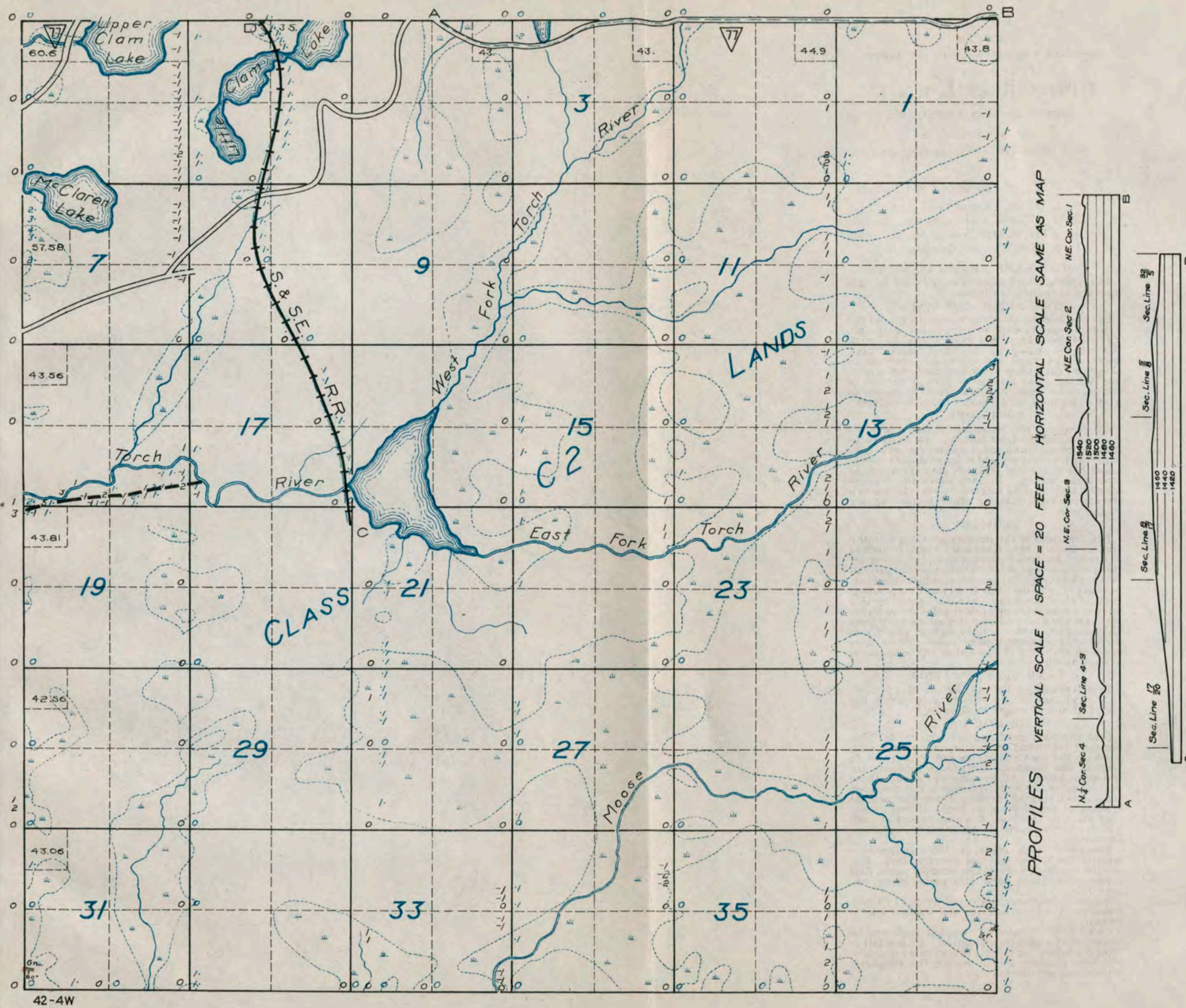
There are areas of magnetic attraction in other parts of the township, but magnetic lines cannot be drawn on the basis of the field work done.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. All lands are placed in Class C2. Lands near granite outcrops have not been classified because of their small extent.

EXPLORATION

A moderate amount of exploration is recommended in section 18. In this exploration it should be borne in mind that the magnetic line may be due to magnetic slates or schist and that the iron formation may be non-magnetic. A series of holes to ledge across and for some distance north and south of the magnetic line would determine the character of the formation causing the magnetic line as well as that of the formations causing the less definite attractions. Much of the work done in exploration for iron ore is wasted because of failure to make intelligent use of the geologic and magnetic data to be obtained by a careful preliminary survey and because the geologic information given by the drill is not properly used as a guide for further work. The value of careful scientific methods of exploration therefore cannot be too strongly emphasized. Before formulating plans for exploration the discussion of this subject in chapter VI, Bulletin XLIV of this Survey should be carefully studied.


Upper Clam Lake
Clam Lake
Little Clam
McClaren Lake
S. & S.E. R.R.
West Fork Torch River
Torch River
East Fork Torch River
Moose River
CLASS C2 LANDS
1
3
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
42-4W
PROFILES VERTICAL SCALE 1 SPACE = 20 FEET HORIZONTAL SCALE SAME AS MAP
N.E. Cor. Sec. 1
N.E. Cor. Sec. 2
N.E. Cor. Sec. 3
Sec. Line 4-9
N. 1/4 Cor. Sec. 4
Sec. Line 32/5
Sec. Line 5/8
Sec. Line 8/17
Sec. Line 17/20
1540
1520
1500
1480
1460
1460
1440
1420

WISCONSIN

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. F. BEAN, DIRECTOR

TOWNSHIP 42 N., R. 4 W.

Survey made in August, 1915

Under the direction of

W. O. HOTCHKISS, State Geologist

AND

E. F. BEAN, in charge of Field Parties

W. L. DOBIE, Chief of Party
R. W. BROWN, Asst. Geologist
D. G. THOMPSON, Asst. Geologist
C. W. HONESS, Asst. Geologist

SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

TOWNSHIP 43N.—RANGE 3W.

SURFACE FEATURES

Though the divide between the Bad River and Chippewa River drainage basins crosses this township, a large proportion of the area is covered by swamps. Two types of topography are found, terminal moraine, and ground moraine. Extending through sections 1, 2, 3, and 4 is a belt of terminal moraine. This has a width of one mile in section one, and a width of one-fourth mile on the west line of section 4. This belt has knob and sag topography with a relief 20 to 35 feet above the ground moraine. In the center of the township there is an area of weak terminal moraine, which is as a rule gently undulating. A belt extends eastward from this along the north of sections 13 and 14. This belt is characterized by ridges and kettles. A belt extending westward into sections 9, 8, and 7, has roughly undulating topography with steep sided kettles. Extending westward through the southern part of sections 16, 17, and 18, is a belt of roughly undulating topography, the local relief growing less toward the west. In sections 28, 29, 32, and 33, the terminal moraine consists of three ridges. An east-west ridge in the southern part of sections 28 and 29 rises about 150 feet above the swamp to the north and 60 feet above the swamp to the south. There are a number of shallow kettles on the slopes. The other two ridges, one in section 32 and the other in section 33, trend north and south and are separated by a swamp. They rise 60 to 70 feet (see profile A–B) above the ground moraine and are roughly undulating. In sections 25, 35, and 36 is a terminal moraine area extending into this township from the east. The topography is gently undulating, and this upland slopes steeply into swamp on all sides. About two-thirds of the township is occupied by ground moraine, with gently undulating topography having an average relief of 10 feet. Swamps occupy a large part of the area.

The materials of the glacial drift are largely sand with some silt and numerous bowlders.

No definite information is available regarding the thickness of glacial drift. Since this is a divide area with slight local relief and rock outcrops are numerous in the townships to the east and north, it is believed that the drift cover averages less than 50 feet in thickness.

A good road has been constructed along the south township line connecting this township with Glidden. The Ashland County road crosses the northeast corner of the township. An old road extends westward from this road to McCarty Lake. The roads in section 36 are good. Settlement is confined to the good roads.

The prevailing timber on the better drained land is hardwood and hemlock. In the swamps are large areas of cedar, tamarack, and spruce. A good deal of the timber in sections 1, 2, 3, 11, 12, 13, and 14, has been cut.

GENERAL GEOLOGY

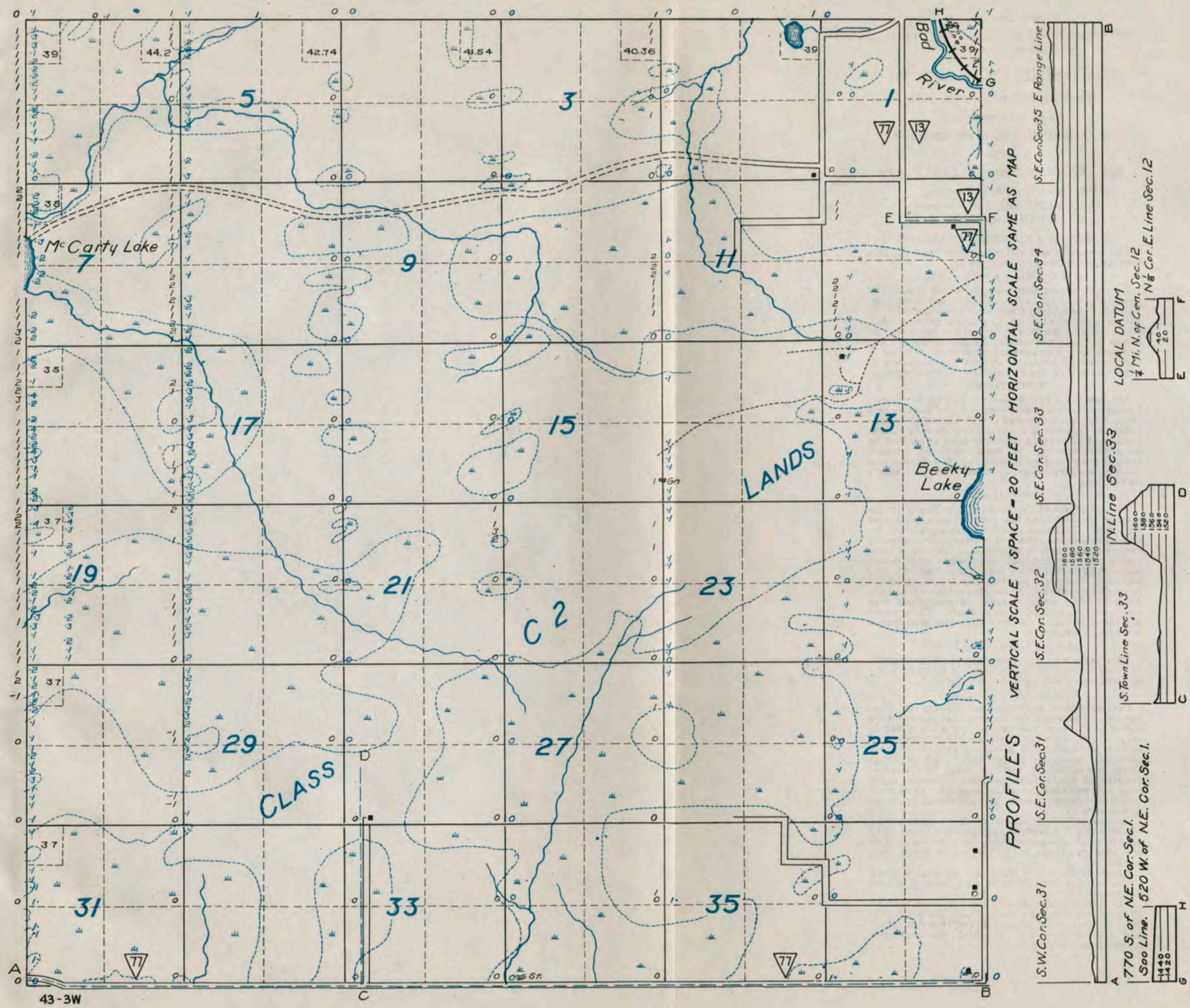
There is a small low exposure of weathered green chlorite schist one tally east of the southwest corner of section 34. There is a second outcrop three tallies north of the southwest corner of section 14. This is a granite gneiss with banding striking east-west. Near the southeast corner of section 29 there are numerous very large bowlders up to 18 feet in diameter. These may indicate underlying ledge. On the basis of this and the granite outcrops in the townships to the east and north all this township except the western part has been mapped as granite. As magnetic attraction is found in the northwestern part of the township and in the township to the west the occurrence of Huronian rocks in this area seems possible. It is possible that some of the area mapped as granite may be underlain by Huronian rocks.

MAGNETIC OBSERVATIONS

A general discussion of magnetic observations and their significance is given in Chapter IV. Light dip readings varying from 1° to 3° occur in sections 7, 8, 18, and 19. Westward attractions are found in the western tier of sections. The discrepancies between the range line readings and those shown on maps of T. 43N.—R. 2W. and T. 43N.—R. 4W. in Bulletin XLIV are due to differences in instruments. The magnetic variations are possibly due to a Huronian formation which may be a slightly magnetic schist, slate, or iron formation.

LAND CLASSIFICATION

A general discussion of the principles of land classification employed in this work is given on page 112. All lands are placed in


McCarty Lake
Bad River
Beeky Lake
CLASS C 2 LANDS
43-3W
PROFILES
VERTICAL SCALE 1 SPACE - 20 FEET HORIZONTAL SCALE SAME AS MAP
LOCAL DATUM
1/4 Mi. N. of Cen. Sec. 12
N 1/8 Cor. E. Line Sec. 12
N. Line Sec. 33
S. Town Line Sec. 33
770 S. of N.E. Cor. Sec. 1
Soo Line. 520 W. of N.E. Cor. Sec. 1.
S.W. Cor. Sec. 31
S.E. Cor. Sec. 31
S.E. Cor. Sec. 32
S.E. Cor. Sec. 33
S.E. Cor. Sec. 34
S.E. Cor. Sec. 35
E. Range Line

WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY
E. F. BEAN, DIRECTOR

TOWNSHIP 43 N., R. 3 W.

Survey made in August, 1915

Under the direction of

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SYMBOLS AND ABBREVIATIONS.

The symbols and abbreviations used on this map are explained in Chapter II.

TOWN AND RANGE LINES.

In constructing this map the south line of the township was laid off as a true east west line. The other boundary lines were then laid off with the lengths shown on the Land Survey plat. Some of the maps are therefore incorrect in shape but this is necessary because definite facts are lacking. The acreage of part of the lots in the north and west tier of sections is shown to give a check on the distances in these sections.

LOCATIONS.

All locations are based on pacing traverses from government land corners. In many cases these were not found and it was necessary to continue the traverse several miles without a check. Locations of certain features may therefore be somewhat wrong. In such cases the feature sought may best be located by its relation to a stream, swamp, lake, or other feature shown on the map.

PROFILES.

The locations of the profiles are shown on the map by dashed blue lines with black letters at the ends. Railroad profiles were furnished by the companies and show elevations of the ground rather than track in most cases: others are from road surveys by the State Highway Commission: most of them are hand level lines made by this Survey. Wherever possible the elevations above sea level are given. These elevations vary from 1335 to 1640 feet. A local datum plane was necessarily assumed in some cases. These cases are identifiable by the fact that the base line is always numbered 0.

LAND CLASSIFICATION.

This is shown on the map by the blue letters. It is explained in the following township description and at length in Chapter V.

MAGNETIC DATA.

Dial compass readings are shown in blue figures. Eastward declinations are shown with a dot to the east and westward with a dot to west of the number. Dip needle readings are shown in black. All are positive except those preceded by the negative sign. All readings show deviation of needles from the normal reading of the instrument used. Normal readings are omitted from the map except at each quarter section corner. All abnormal readings are shown.

Traverses were made on lines indicated—usually the N-S section and quarter lines. Dip needle readings were taken each 50 paces, dial compass readings each 100 paces when sun permitted.

Magnetic lines are indicated by heavy black lines, solid where definite and dashed where doubtful.

CAUTION: Almost any kind of rock may be the cause of magnetic attraction. Do not fail to read the following description of this township, and also chapter IV, in which the magnetic attractions are discussed.

Class C2 since there is little positive evidence upon which to base a more definite classification.

EXPLORATION

Until exploration in T. 43N.—R. 4W., shows the cause of the attraction there, exploration in this township would be unwise.

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