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E. A. BIRGE, Director. C. R. VAN HISE, Consulting Geologist.

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PRELIMINARY REPORT

ON THE

COPPER-BEARING ROCKS

OF

DOUGLAS COUNTY, WISCONSIN.

SECOND EDITION.

CONTAINING A PRELIMINARY REPORT ON THE COPPER-BEARING ROCKS OF PARTS OF WASHBURN AND BAYFIELD COUNTIES.

BY

ULYSSES SHERMAN GRANT,
Professor of Geology in Northwestern University.

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PREFACE.

The field work which furnished the basis for the first edition of this Bulletin, published early in 1900, was done in the summer of 1899. During the summer of 1900 further study on the copper-bearing rocks was undertaken, and the present edition contains a preliminary report of both seasons' field work. In the second edition pages 1 to 42 (the introduction and chapters I to III) and plates I to XI are identical with those of the first edition; chapter IV (on the Minong copper range) and plates XII and XIII have been added; and chapter V (chapter IV of the first edition) has been enlarged and in part rewritten. In chapter IV an account of the geology of the Minong copper range, in so far as it differs from that of the St. Croix and Douglas ranges, is given in addition to the descriptions of special localities.

The maps for both editions were drawn by Mr. Frank J. Huse, of Evanston, Illinois.

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INTRODUCTION.

The field examinations which form the basis for this report were made during the summer of 1899. In considering the time available in one season it became apparent that a detailed examination of all the rocks in northern Wisconsin, in which copper might occur, was out of the question. Moreover, we already have a fairly good knowledge of the general geology of this part of the state. It therefore seemed advisable to concentrate the work in certain districts, as a careful study of certain important areas was more likely to produce results of value than the superficial examination of a large area. At the same time it was expected that the future would permit a careful examination of other districts in the state underlain by the copper-bearing rocks. With these points in mind the work of this season was concentrated first on the rocks which lie along, but north of, the St. Croix river in the southwestern part of Douglas county, and second, on those which form the first hill ranges south of lake Superior in the northern part of the county, and in which explorations for copper are being actively prosecuted. The district first mentioned,—i. e., the southwestern, or what is called in this report *the St. Croix copper range,*—presented, in its geological structure, a more simple problem than the northern, or *the Douglas copper range,* and was accordingly examined first.[1]

[1]The northern range has been known as "the South range" and as "the Douglas County range," while the southern has received no name, or has been included with the northern. The two ranges, while alike geologically, are distinct geographically, being separated by a belt of country several miles in width in which there are practically no rock exposures, and it is expedient to have a distinct name for each. The writer understands that the names used above,—Douglas range and St. Croix range,—are coming into use among those interested in the exploration for copper in northern Wisconsin, and these names have been adopted in this report.

This examination was made between the 17th of May and the 20th of June. The remainder of the season, until the last of August, was spent on the northern district. But during this time a visit was made, for the purpose of comparative study, to the copper-mining region of Keweenaw point.

The method followed in the season's field work was to visit all parts of the two areas above mentioned which were known to have rock outcrops, or in which outcrops might be reasonably expected. In such parts north and south traverses were made at intervals of one-half mile, or more frequently when occasion demanded. Thus, in the region where outcrops occur frequently, the north and south section lines, the north and south quarter section lines and some of the east and west section lines were followed. The larger streams, and in fact all the streams which might be expected to cut down to the bed rock, were also followed. The outcrops seen were located carefully by pacing, and the position of each was indicated as so many paces north and so many paces west of the southeast corner of the given section. In this manner of locating 2,000 paces equals one mile. Rock samples were taken from most of these outcrops. In all about 775 rock numbers and a considerably greater number of specimens were collected.

Because of the active interest which is being manifested in the copper deposits of northern Wisconsin, it was deemed best to publish a report on the district without unnecessary delay. Accordingly this report is presented with the hope that it will be of service to those who are at present engaged in exploration for copper, or who are interested in the material development of this part of the state. It should be borne in mind, however, that this report was written before it was possible to make a careful study of the whole district underlain by the copper-bearing rocks, and even before it was possible to make an exhaustive study of the facts and specimens collected in those areas in which the work was concentrated. Thus this report is necessarily of the nature of a preliminary rather than of a final report. At the same time it should be stated that the essential facts concerning the geological structure of the areas examined, the geographical distribution of the different rocks, the manner of occurrence of the copper deposits, and the general distribution of these deposits have been determined by the work already done. It is accordingly expected that the facts here presented are correct and that future work will tend to confirm rather than to alter them.

It is manifestly impracticable for parties of the Wisconsin Survey to discover every outcrop of the copper-bearing rocks in the state, especially when these outcrops are of small extent, are far removed from each other and are accessible with difficulty. It is therefore requested that individuals, who know of solid ledges of rock anywhere in the northern part of the state, communicate with the Survey, giving as nearly as possible the exact location of these ledges. If convenient, small samples illustrating the rocks should be sent.

Acknowledgements. In the field work the writer was assisted by Dr. C. P. Berkey, Instructor in Mineralogy in the University of Minnesota, who had previously had experience in studying the copper-bearing rocks in the district of Taylors Falls and St. Croix Falls on the St. Croix river. It was exceedingly fortunate that Dr. Berkey's services were available in this work, both on account of his knowledge of the copper-bearing rocks and also because it made it possible to discuss and investigate jointly in the field certain important problems. Mr. Charles Cole, of South Range, and Mr. A. L. Hinman, of Downing, and in the latter part of the season Mr. R. B. McLean, of Superior, acted as compassmen and located all the outcrops seen. Their knowledge of woodcraft and their acquaintance with the county examined aided materially in the season's field work. To the Director of the Survey, Prof. E. A. Birge, and to the Consulting Geologist, Prof. C. R. Van Hise, and to Mr. C. K. Leith the writer's thanks are especially due for a large number of courtesies. The work was undertaken and carried on under the direction of Prof. Van Hise, who spent several days in the field reviewing important points and who was especially helpful in suggestion and advice regarding the work. The analyses were made by Dr. W. W. Daniells, Professor of Chemistry in the Uni-

versity of Wisconsin. One fact became particularly apparent during the season spent in this examination; it was the universal and cordial interest shown in the work of the Survey by the people of Douglas county. Their willingness to coöperate in whatever manner possible was very marked. Among these people was Mr. Ernest A. Arnold, of West Superior, who generously placed his knowledge of the county and a considerable part of his time at the disposal of the Survey.

CHAPTER I.

GEOLOGY OF DOUGLAS COUNTY.

Douglas county is the northwestern county of Wisconsin. It is bounded on the north by St. Louis county, Minnesota, and by lake Superior; on the east by Bayfield county, Wisconsin; on the south by Burnett county, Wisconsin; and on the west by Pine and Carlton counties, Minnesota. Douglas county comprises all those parts of townships 43 to 49, Ranges 10 to 15, which lie in Wisconsin. The total area of the county is 1336 square miles.

PREVIOUS DESCRIPTIONS.

The following are the more important papers which refer to the copper-bearing rocks in this county:

T. C. Chamberlin. "General Geology"; Geol. of Wis., vol. I, pp. 96–118, 1883. "Economic Geology"; Ibid., pp. 656–661.

R. D. Irving. "General Geology of the Lake Superior Region"; Geol. of Wis., vol. III, pp. 7–15, 1880. "The Copper-Bearing Rocks of Lake Superior"; U. S. Geol. Survey, Monograph V., pp. 234–259, 1883.

Moses Strong. "Geology of the Upper St. Croix District" (edited by T. C. Chamberlin); Geol. of Wis., vol. III, pp. 363–428, 1880.

E. T. Sweet. "Geology of the Western Lake Superior District"; Geol. of Wis., vol. III, pp. 303–362, 1880.

The report by Strong deals especially with the St. Croix range; that by Sweet with the Douglas range and gives an account of the earlier explorations for this metal. These reports are out of print. Both ranges are discussed by Irving in "The Copper-Bearing Rocks of Lake Superior."[1]

[1] This book contains the best and most complete account yet published of the copper-bearing rocks in the Lake Superior district and will prove of value to any one interested in the geology of these rocks. It can be procured from the Director of the U. S. Geological Survey, Washington, D. C. The price is $1.85.

SURFACE FEATURES.

The surface of Douglas county, considered broadly, is comparatively level; there are no districts which approach the mountainous, nor are there certain parts which are elevated many hundreds of feet above other parts. When examined in detail, however, this surface presents some marked features and can readily be divided into several distinct zones, each of which is characterized by certain peculiarities of topography. It may be stated that these different topographic zones correspond, in general, to the belts of rock which underlie the glacial deposits. There are five of these topographical zones. They are described below, beginning at the north.

I. That part of the county which borders on lake Superior is a plain. This plain is from five to twelve miles in width and extends from the lake shore southward to the northern edge of the hills which form the Douglas range. The plain slopes gently toward the north, and, while this slope is sufficient for drainage, to the eye the ground frequently appears perfectly level. At the town of South Range, about six miles from lake Superior, the plain is 164 feet above the lake level, and a mile farther south it ends abruptly against the northern flank of the Douglas range. This topographic district is underlain by till and by water-deposited clays which were laid down when the waters of the Lake Superior basin were at a considerably higher level than at present. Beneath these superficial deposits is the Lake Superior sandstone, and the outlines of that formation are the outlines of this plain (see geological map, plate I).

II. The hills which form the Douglas range rise abruptly, from the plain just mentioned, to a height of from 100 to 300 feet. The marked escarpment formed by the northern slope of these hills is a very noticeable feature of the topography, especially when viewed from the plain to the north. This escarpment is analogous to the still more marked escarpment which rises, in Minnesota, from the northern edge of the plain. This hill range, which forms the second topographical district, extends east and west through the county, taking towards the west, however, a west-southwesterly direction. The hill range is from one to four miles in width, and its southern slope is much more gentle than its northern. On the south it merges gradually into another zone of different topography. The rocks underlying, and very frequently coming to the surface, in this hill range are igneous rocks of Lower Keweenawan age, and in places superimposed on these rock hills are hills of drift, especially in the north half of T. 47 N., R. 11 W., and in the southwest quarter of T. 47 N., R. 14 W.

III. To the south of this hill range and extending nearly to the St. Croix river is a comparatively level tract of land in which prominent elevations are uncommon. Here the ground is frequently so level that extensive swamps exist. This district is underlain by glacial drift, largely in the form of till, while below the drift and rarely outcropping, are the igneous rocks of Lower Keweenawan age.

IV. What are known as "the barrens" form a sandy plateau which stretches northeast and southwest through the county. The surface of this plateau is at times noticeably hilly and is also supplied with depressions in which are frequently lakes. The northwestern border of this tract enters the county near the St. Croix river in T. 43 N., R. 14 W., extends northeastwardly and crosses the eastern border of the county in T. 47 N., R. 10 W. The St. Croix river and the Brule river for a considerable distance flow in the barrens, but near their northwestern border. The southeastern border of the barrens is approximately the same as the southeastern border of the sandstone of the Upper Keweenawan,—in fact the area underlain by rocks of this age is practically the area occupied by the barrens. (See plate I.)

V. The extreme southeast corner of the county, i. e., that underlain by the rocks of the Lower Keweenawan age, is very similar to the third topographic district mentioned above, except that the underlying rocks more frequently outcrop through the till.

The streams of the county are all comparatively young and consequently do not possess broad, deep valleys. The streams of the plain which borders on lake Superior have cut shallow steepsided troughs into the unconsolidated deposits which form the surface of the plain. The divides between these streams are wide and flat-topped. Many of these streams head on the northern flanks of the hills which form the Douglas range. The larger streams flow directly across this range, and, where they pass from the range to the plain to the north, have cut noticeable gorges, the most marked of which are along Black river and Copper creek. Commonly along these gorges are rapids or waterfalls. The best known of these is Black River falls (see plate II) which is 110 feet in height. To the south of this plain the streams have very shallow channels. The only exception to this last statement is the St. Croix river, which has cut down 100 or more feet into the unconsolidated drift deposits through which it flows. This river flows in a broad, flat-bottomed valley which is out of proportion to the size of the present stream. The valley was excavated when the St. Croix acted as the outlet for the waters of the Lake Superior basin, the water level of the lake then reaching and overflowing the divide between the headwaters of the present Brule and St. Croix rivers.

SKETCH OF THE DIFFERENT FORMATIONS.

The rocks of Douglas county are readily separable into three distinct series (see geological map, plate I), as follows, in descending order:

Cambrian: Lake Superior sandstone.
Upper Keweenawan: Conglomerates, sandstones, and shales.
Lower Keweenawan: Igneous rocks, largely basic lava flows.

The oldest rocks exposed in the county are of Lower Keweenawan age. They consist of igneous rocks which are almost always basic in nature and which are largely in the form of lava flows. These lava flows, in the northern part of the county, dip toward the southeast or south, while in the extreme southeastern corner of the county are similar rocks dipping toward the northwest. Younger than these and resting directly upon them are a series of conglomerates, standstones and shales of Upper Keweenawan age. Younger still is another series of rocks, mainly sandstones, which outcrop in many places along the southern

Black River Falls. 110 feet high. S. E. ¼ Sec. 21, T. 47 N., R. 14 W.

shore of lake Superior and to which the name Lake Superior sandstone has been applied.

The Lower Keweenawan rocks are the ones which contain the copper deposits.

THE LOWER KEWEENAWAN.

These rocks are of the same age and of the same origin as the copper-bearing rocks of Keweenaw point in which the most extensive deposits of native copper known in the world occur. Moreover, in lithological character the rocks of the two areas are the same in all broad features and in most minor features. The belt of these rocks in the southeastern corner of Douglas county is directly continuous geographically and geologically with the same rocks on Keweenaw point, and the Lower Keweenawan rocks of the northern part of the county are unquestionably continuous, beneath the surface, with those in the southeastern corner of the county (see section AB, plate I).

Sedimentary Rocks.

The only sedimentary rocks which have been reported from the Lower Keweenawan of Douglas county are certain beds of conglomerates lying between lava flows in the southeastern part of the county. These conglomerates are composed of débris derived from the closely adjacent, underlying, igneous rocks. Careful search was made for such conglomerates in the northern belt of Lower Keewenawan rocks, but no indication whatever that such exist was discovered. It is of course possible that such conglomerates do exist here interbedded with the lava flows, and future search may bring them to light. Should they be found, the close parallel in lithology between the rocks of this district and those of Keweenaw point would be practically complete. Moreover, it is known that such interbedded conglomerates exist in this northern belt of lava flows on the Snake river in Pine county, Minnesota, and also on the north shore of lake Superior.

Igneous Rocks.

In general these lava flows are dark colored and basic (i. e., low in silica) in character. To such rocks the non-committal name of *trap* can be conveniently applied. It is not necessary at this place to enter upon a detailed analysis of the different kinds of rocks included under this comprehensive and elastic term, but a few of the commoner types should be mentioned.

The term *diabase* is applied to a rock composed essentially of lath-shaped plagioclase feldspars and of augite, the latter mineral filling in the angular spaces between the feldspars. These rocks are commonly of such fine grain that this relation between the minerals can be determined only by a microscopic examination. Frequently one grain of augite completely surrounds one or more of the feldspars. These augite grains vary in size from very minute ones to those an inch across. When they become of noticeable size and include many feldspars, the rock has a mottled appearance due to reflections from the cleavage faces of the augites, and such a rock is known as a *luster mottled diabase.* Most commonly such rocks contain olivine and are then known as *melaphyres.* The melaphyres become prominent rocks in places, especially in the St. Croix range, where the augite grains are not uncommonly a quarter of an inch across and the feldspars, on account of their color or their minute size, are usually clearly seen only under the microscope.

Gabbro is composed of the same minerals as diabase, but the constituent grains are of approximately uniform size and shape. The gabbros found in Douglas county are usually of considerably coarser grain than are the rest of the Keweenawan rocks.

A *porphyry* is a rock which contains crystals of one or more minerals imbedded in a groundmass which is of much finer grain when compared with these porphyritic crystals.

An *amygdaloid* is a rock which contains roundish cavities which have been more or less filled by secondary minerals. These cavities are due to gas which escaped from the molten lava on cooling. They vary in size from those of microscopic dimensions to those which are an inch or more in diameter.

The minerals which occur most commonly in such cavities are quartz, calcite, epidote, chlorite, and prehnite. Native copper also occurs.

The last two names,—porphyry and amygdaloid—are textural terms and are also applicable to acid (i. e., those high in silica) igneous rocks, but such are rare in Douglas county. The acid rocks seen are granites, syenites, and quartz-porphyries. *Granite* is composed of quartz and orthoclase feldspar with one or more of the following minerals: mica, hornblende and augite. The grains are of approximately uniform size and shape and the rock is in general coarser grained than the ordinary traps. *Syenite* is the same as granite except for the lack of quartz. *Quartz-porphyry* is a porphyry which has porphyritic crystals of quartz and the mineral composition of granite.

Most of the rocks of the Lower Keweenawan are in the form of lava flows and almost all of these are basic in character. In only one place (on Copper creek) were lava flows seen which approached an acid composition. Quartz-porphyry, however, undoubtedly exists in small quantities associated with these basic lava flows, for a few pebbles of such rock occur in the conglomerate at the base of the Upper Keweenawan. Whether this quartz-porphyry exists in the form of lava flows or intruded masses is not known. A few of the diabases, and possibly some of the melaphyres, occur as intruded sheets or dikes in the surrounding lava flows, and the gabbros, granites, and syenites are all intrusive. These intrusive rocks are most common along parts of the Aminicon and Middle rivers in the northern half of T. 47 N., R. 12 W., and the southern half of T. 48 N., R. 12 W.

Basic Lava Flows.

We are accustomed to think of lava flows as coming from volcanic mountains. In such a case the different flows from any one volcano would be arranged in roughly concentric belts dipping away in all directions from the central mountain. But in the flows here considered there is no such arrangement. They extend over long distances with comparatively uniform thickness and dip and strike. There are no evidences of volcanic mountains. It is therefore commonly thought that the lava flows of the Lower Keweenawan came, not from one volcanic mountain nor from a series of such, but from extensive fissures in the earth's crust. In no other manner can we account for the uniform thickness, dip and strike of these lava flows over long distances. From these fissures welled out molten material which flowed away as far as the slope of the surface and the rapid cooling of the mass permitted. After each flow there was a longer or shorter period of inactivity followed by another flow. Thus there was built up, flow upon flow, a vast thickness of igneous rock.

The different flows vary much in thickness, and even the same flow may vary in thickness from place to place. The thinnest flows seen had a thickness of about two feet, and from this size there are flows of various thicknesses up to those of a hundred or more feet. The larger flows are more continuous, both along the strike and also along the dip, than the smaller. At times these larger flows can be traced along the strike for several miles. One of the belts of melaphyre, which appears to be all one mass of rock, on the St. Croix range can be seen at intervals for a distance of over twenty-two miles.

Dip and Strike. The original angle of slope of these flows undoubtedly varied, but the average was a smaller angle than they now have. Thus it is seen that the whole series has been tilted somewhat from its original position. This is especially true of the rocks of the Douglas range where the dip varies from 30° to nearly vertical. The dip on the St. Croix range is lower, averaging less than 20°. On both ranges the dip is toward the south or southeast. The strike on the Douglas range is about northeast near the western end, but, on going eastward, gradually assumes a higher angle with the north, and at the eastern end of the range it is east and west.

Separation of the Different Flows. The copper deposits of the district are usually found at the top of one flow or at the bottom of the next overlying flow. From the fact that the copper deposits occur thus,—as it were between two flows,—it becomes a matter of prime importance to be able to distinguish one flow from another and to determine where one flow ends and the next overlying one begins. This is not only of importance in the search for copper, but is also of value in determining the sequence, dip, and strike of the flows and the general geological and structural features of the region. Some of the characteristics by which one flow can be separated from another are given below:

I. Two flows may differ by certain features, such as color, coarseness of grain, mineral composition, hardness, texture, absence or presence of porphyritic crystals or of amygdules, or one may be affected more by the weather than another. Where two or more, or at times even one, of these features markedly differ in two adjoining flows, the separation is easily made.

II. Each flow is of finer grain at the bottom and at the top than in the center. This is not especially marked in those flows of only a few feet in thickness, but in the thicker flows this feature is found to be quite prominent when a careful examination is made. Commonly in the central parts of the thicker flows the different grains can be easily distinguished by the unaided eye, while it is very usually the case that on going from the center toward the upper and lower parts of the flow, the grain gradually becomes finer until the different grains can be distinguished only by a microscopic examination. On the upper surface the rock may become even glassy.

III. In most of the flows amygdules are developed near the upper surface, and, much less commonly, amygdules of smaller size than those near the upper surface are seen near the lower surface. Some of the thinner flows are amygdaloidal from bottom to top. It is the rule, however, that the upper few feet,—from two to ten or even twenty feet,—of a flow is amygdaloidal and that the amygdules decrease in size and number as you go farther from the upper surface. This presence of the amygdaloidal texture in the upper part of a flow is one of the commonest criteria by which two flows can be separated.

IV. The upper part of a flow frequently presents a fragmental appearance. This may be due: (1) to a breaking-up of the hardened upper crust of a flow by the onward movement of the still liquid mass beneath, the result being a confused mass of fragments cemented by rock of nearly the same nature; (2) to a breaking-up of the upper surface of a flow by the elements, and its subsequent cementation by its own debris or by the next overlying flow; (3) to volcanic fragmental deposits,—bombs and ashes,—deposited on the surface of one flow during the interval between its consolidation and the extrusion of the next flow. This fragmental upper part of a flow, when present, varies in thickness from an inch up to several feet. The fragmental character of the upper portion of one of these flows is shown in plate III.

V. The upper surface of a flow may show a ropy structure or other peculiar surface structures,—structures which are common to the surfaces of many lava flows, but which are not frequently seen in the old lavas here considered.

VI. In the adjustments which took place between the different beds in the tilting of these rocks from their original positions fissures were formed, and these would form in the weakest planes of the rock, i. e., in the loosely textured upper part of the flow or along the division line between two flows. Such a fissure is frequently accompanied by a more or less marked brecciation of the walls of the fissure. This criterion cannot be relied upon when all other criteria are absent, but it is of value as one feature which, in connection with others, helps to establish a division between two flows.

VII. One marked feature of the topography in districts where the Keweenawan rocks are not covered by later material is a peculiar step-like surface. The different steps vary in size according to the thickness of the individual flows, some of the smaller steps being shown in plate III, and one of the larger ones in plate IV. This step-like character presents itself as follows: When one approaches from the north a ridge composed of outcrops of several flows he first encounters a very steep, northward-facing slope, or even a precipitous wall, which indicates, nearly, the thickness of the lowest flow. At the top of this wall is a gentler slope to the south, the slope coinciding practically with the dip of the rocks and marking the upper limit of the flow approximately but not exactly, for usually some of the loosely textured upper part of the flow has been removed by erosion, glacial or otherwise. On following down this slope for a short distance another very steep slope, or precipitous wall, is met, beyond which the more gentle southern slope and the steeper northward facing slope is repeated indefinitely. Many of the ridges on the Douglas range show this peculiar step-like outline. Where the flows are quite thick valleys, elongated in the direction of the strike, mark the separation between two flows. A typical case of this kind is illustrated in plate IV, the slope on the left indicating the dip and approximately the upper surface of one flow, while the steep wall on the right marks approximately the thickness of the next overlying flow.

THE UPPER KEWEENAWAN.

The Upper Keweenawan rocks form a broad belt which extends northeast and southwest through the southeastern part of the county (see geological map, plate I). They are flanked on both sides by the Lower Keweenawan rocks. The strata of the Upper Keweenawan are of sedimentary origin and consist of conglomerates, sandstones, and shales. The only places where rocks of this age have been examined by the writer are at certain localities along the St. Croix river and its tributaries in Ts. 44 N., R. 13 W., 43 N., R. 13 W., and 43 N., R. 14 W. (For location of outcrops of rocks of this age, see plate VII.) Here the conglomerates, which are interbedded with, and succeeded upwardly by the sandstones and shales, lie apparently conformably on the underlying igneous rocks and dip toward the southeast at angles of from 10° to 18°. The strike is almost exactly northeast.

On the lower part of Crotty brook, near the center of the west side of Sec. 8, T. 43 N., R. 13 W., there is a considerable exposure of rocks of Upper Keweenawan age. They consist of interstratified conglomerate, sandstone and shale, all reddish brown in color. The pebbles of the conglomerate are of all sizes up to six inches in diameter and are well rounded. They consist of fine grained igneous rocks similar to rocks which are known to occur in place a mile or more to the northwest, with the exception of some pebbles of quartz-porphyry which rock is not known to outcrop in this vicinity. The matrix of the conglomerate is sandstone cemented at times by calcite, and this matrix and the purer beds of sandstone do not, except in very small part, consist of quartz sand, but of material which was derived from basic igneous rocks. The strike is N. 45° E. and the dip 12° to 14° to the south of this. On the same stream, near the center of the east side of Sec. 7, T. 43 N., R. 13 W., is a small exposure of conglomerate. Farther up the stream are no other exposures of sedimentary rocks, but fragments of conglomerate are rather common nearly up to the traps which occur in the northwest quarter of the same section. The boundary of the Upper Keweenawan is thus most probably very close to the most southern of these trap outcrops.

On the Moose river the most northerly exposure of conglomerate is on the east side of the river and close to the south line of Sec. 14, T. 44 N., R. 13 W. This is a small exposure, but directly across the river is an exposure of trap, thus allowing the division line between the two parts of the Keweenawan to be located with precision at this place. On the west bank of the river, a short distance below the outcrops just mentioned, are other outcrops of conglomerate interbedded with a sandstone which forms the matrix of the conglomerate. The pebbles here are of all sizes up to those fifteen inches in diameter, and practically all, except some half an inch or less in diameter, are well rounded. The pebbles are of trap of various kinds, but among them no melaphyre nor quartz-porphyry was found. The sandstone is of yellow color and consists of fine fragments of the traps cemented by epidote and calcite. The strike is approximately N. 40° E., and the dip 13° to the south of this. Exposures of conglomerate and interbedded sandstone continue at intervals down the river almost to the bridge which is in the S. E. $\frac{1}{4}$, S. E. $\frac{1}{4}$, Sec. 27, T. 44 N., R. 13 W. The sandstone varies in color from yellow, through gray, to brownish red.

Upper surface of Lava Flow. S. E. ¼ Sec. 2, T. 47 N., R. 13 W.

THE LAKE SUPERIOR SANDSTONE.

All of Douglas county north of the Douglas range is underlain by this sandstone. Outcrops along the Lake Superior shore in Douglas county have not been reported, but the larger streams have at times cut down through the glacial and lacustrine deposits to the underlying sandstone; this is especially the case near the southern border of the sandstone area. Outcrops also occur on the St. Louis river at the northwestern corner of the county.

The sandstone lies nearly horizontal. Toward the southern border there is a slight dip toward the north and in close proximity to this border, as will be mentioned below, the sandstone is in places much disturbed.

In lithological character the Lake Superior sandstone, at least as exposed in Douglas county, is decidedly different from the sandstone of the Upper Keweenawan. The latter is a sandstone composed of fragments of basic igneous rock while the former consists essentially of quartz sand. In a few places, as at the contact with the traps on the Black and the Aminicon rivers, the lowest exposed strata of the Lake Superior sandstone consist of a conglomerate, and at the former locality the conglomerate contains, in addition to the pebbles of basic igneous rock, a considerable percentage of quartzite pebbles. Some of the higher strata of the Lake Superior sandstone are rich in clayey material and some layers are typical shales. In color the sandstone varies from white to reddish brown, and frequently in small areas there is much mottling due to these two colors.

JUNCTION OF THE LAKE SUPERIOR SANDSTONE WITH THE TRAPS.

The junction of the Lake Superior sandstone with the Lower Keweenawan is marked by a distinct fault. On the north side of this fault line the strata have been relatively depressed, while on the south side they have been relatively elevated. We thus find the Lake Superior sandstone, which is younger than the traps of the Lower Keweenawan and originally overlay them, today at a lower horizon than the traps. The actual amount of displacement along this fault line has not been carefully determined, but in some places it is probably several hundreds of feet.

The rocks on each side of the fault have been affected differently by this displacement, as described below.

Effects on the Traps.

Along the fault line the traps have been remarkably shattered. This shattering becomes more prominent, and the fragments into which the rocks are broken become smaller, as the contact line is approached. The marked brecciation of the traps commonly extends, not only for a few feet from the sandstone contact, but to a distance of 400 feet or even farther. The extreme fineness of this brecciation is a very marked feature. In many outcrops the traps are seen to be so thoroughly shattered that it is impossible to find a fragment of the rock more than an inch across which is not divided into smaller pieces by cracks. On weathering, or by a blow from the hammer, such a rock breaks down in small, angular pieces. One good example of this brecciation of the traps near the sandstone contact is shown in plate V.

The displacement which occurred along the fault is thus seen to have been distributed, at least in part, through a considerable thickness of rock, so that the fault plane is, in this case, a "plane" which is a number of feet in thickness.

This brecciation of the traps, together with the marked topographic break which occurs at the junction of the sandstone and traps, becomes an important aid in determining the northern border of the Keweenawan rocks and thus the line north of which explorations for copper need not be carried. There are other places where the traps have been brecciated, as already mentioned, but here the brecciation is commonly confined to the line between two flows and the brecciated mass is at most only a few feet in thickness.[1]

[1] See under VI on page 14.

Fault Breccia in the Traps. Middle river contact of Traps and Lake Superior Sandstone.

Effects on the Sandstone.

As a rule the sandstone does not show this marked brecciation near the contact. Only in one place,—at the Middle river contact in Sec. 25, T. 48 N., R. 12 W.,— does the sandstone exhibit evidence of so complete a shattering as do the traps. But the sandstone has been affected in a different manner and has been thrown into folds, or broken into large, faulted blocks.

Black River Contact. For a short distance below Black River falls the river flows in a gorge cut in the traps, but within 800 feet of the falls the Lake Superior sandstone occurs in a few isolated exposures. These dip in various directions, and in one place strata of the sandstone are found included in the trap breccia which exists near the contact line. Some 200 feet farther down the river the sandstone is exposed more continuously and near the contact the dip is 35° toward the north. Farther north the dip becomes less and the sandstone, except for a few minor undulations, becomes practically horizontal. The general effect on the sandstone at this contact is a bending upward of the beds near the fault line, while in the immediate vicinity of the contact there has been some faulting of the sandstone.

Copper Creek Contact. Here, on the west bank of the stream, the two rocks occur within ten feet of each other. The trap shows a precipitous wall facing north and rising some fifty feet above the stream, and ten feet to the north of this is an exposure of sandstone rising fifteen feet above the water. The sandstone dips toward the north an at angle of 60°, while a few feet farther from the contact the dip is 40° toward the north, and within a distance of 100 feet from the contact the sandstone has become practically horizontal. The bending upward of the sandstone beds at this contact is represented in the section on plate VIII.

Aminicon River Contact. Here the contact plane, as exposed, dips to the south at an angle of 45°. At the contact the sandstone has been sharply flexed upward and also probably faulted. Within forty feet of the fault plane the sandstone is nearly horizontal and continues so, with the exception of a few minor irregularities, to the sandstone quarry, about half a mile to the northwest. See section AB on plate IX.

Middle River Contact. The contact between the sandstone and the traps is crossed three times by this river in Sec. 25, T. 48 N., R. 12 W., and the exposures are such as to render this contact of more interest than any of the others. The upper layers of the sandstone, as seen here, are shaly sandstones or red and gray shales with some bands quite rich in lime. In the immediate vicinity of the traps the shaly sandstone is very much brecciated, to as high a degree as the brecciation of the traps before described.[1] The sandstone has been thrown into a marked series of folds, so that the dip is, for a distance of nearly half a mile from the contact, at a high angle toward the south. This dip varies from practically vertical near the contact to 40°, the average in this half mile being nearly 70°. (See plate VI.) At the contact there is perhaps a sharp synclinal fold so that for a few feet the dip is toward the north. Beyond this half mile (i. e., to the north) exposures are not very continuous, but such as occur show first flat dips, dips of from 40° to 60° toward the north, dips of 20° toward the south, and lastly horizontal strata. All these occur within a mile and a quarter of the contact. The section CD, on plate IX, shows the folding of the rocks as above described.

THE LATER FORMATIONS.

In Douglas county there are no strata known which are younger than than the Lake Superior sandstone and older than the glacial drift. No attempt was made in the examination of the copper-bearing rocks to investigate the drift deposits of the county. It is only necessary to state that the glacial deposits take three distinct forms: (1) unstratified drift or till which exists largely in the second, third, and fifth topographic districts already described;[2] (2) stratified drift, which exists in the barrens or the fourth topographical district; and (3)

[1] See p. 18 and plate V.
[2] Pp. 6-7.

Tilted strata of Lake Superior Sandstone. Middle river, contact of Traps and Lake Superior Sandstone.

clays deposited near the end of the Glacial epoch in the Lake Superior basin. These are underlain by, and mingled with, the unstratified drift and the two together form the marked red clays which cover the northern part of the county.

GEOLOGICAL STRUCTURE.

To the statements already made it is only necessary to add that the structure of the Keweenawan rocks is that of a syncline, with the synclinal axis running northeast and southwest through the center of the tract underlain by the rocks of Upper Keweenawan age. To the southeast of this axis the strata dip northwest, while to the northwest of it the dip is toward the southeast and south. This fold is a very open and shallow one, the dips near the center being small, while on the edges they become more steep, here averaging perhaps 40°. (See section on plate I.)

The junction between the Keweenawan traps and the Lake Superior sandstone on the north is marked by a fault, as has already been described. The sandstone dips at a very low angle toward the center of the Lake Superior basin, or is practically horizontal.

Joints.

Intersecting the strata of the Keweenawan, both the sandstones and the traps, are frequently joint planes. There are commonly two series of these, one coinciding practically with the dip and the other at right angles to the first and running with the strike. There are also frequently joints of another system which are practically at right angles to those of the first system and run with the direction of the dip. In outcrops where the dip and strike cannot be definitely determined these joints, especially those of the system which coincides with the dip, give an indication, but not always a reliable one, of the dip and strike.

GEOLOGICAL HISTORY.

In a very early period (Algonkian) of geological time, but later than the deposition of the rocks which contain the iron ores of the Lake Superior district, Douglas county was being covered by successive flows of molten rock. These flows were built up, one on top of another, until a mass of igneous rock several thousands of feet in thickness had accumulated. These are the rocks of the Lower Keweenawan age. These flows at last ceased and were followed, without any great lapse of time, by the deposition of a series of sedimentary rocks of Upper Keweenawan age. These sediments lie above and conformably upon the older lava flows, and consist essentially of material derived directly from these lava flows. After the deposition of these sedimentary rocks the land was raised above sea level, where it stood, exposed to erosion, for a long period of time. Some time after the deposition of Upper Keweenawan rocks, and quite probably accompanying the elevation of these rocks above the sea, compressive forces acting in a general northwest and southeast direction flexed the strata into their present synclinal form (compare section AB on plate I). Later the region, or at least the northern part of it, was again covered by water, and in this water were deposited the strata of the Lake Superior sandstone. These strata are of Cambrian age and were deposited in an approximately horizontal position,—a position they have largely retained to the present day. At some unknown time after the deposition of the sandstone the district was visited by an east and west fissure, along which there was a displacement of the rocks. This is the fault already described which at the present time separates the Lake Superior sandstone from the Keweenawan traps. The downthrow was on the north side of the fault line.

During all the long ages which have elapsed from the time of the Lake Superior sandstone (Cambrian) until the present day Douglas county seems to have been above water,—at least there are today no remnants of strata younger than the Cambrian. It is possible, of course, that such strata might have been deposited and afterwards removed by erosion. The glacial deposits which now so universally cover the bedrock throughout the county owe their origin to the ice sheet which covered the northern part of the United States in, as it were, the geological yesterday.

GEOLOGICAL MAPS.

Accompanying this report are four geological maps. The first (plate I) is a general geological map of Douglas county. The others (plates VII, VIII and IX) are more detailed maps of limited areas. The extent of each of these detailed maps is indicated on the map of Douglas county. On the detailed maps practically all of the data (except the topography and such features as the abundance of certain kinds of boulders) which the Survey depends upon in locating the boundaries between the different formations are presented. The maps then will enable one to tell at a glance how accurately the boundary lines between the different formations are drawn, the accuracy being a direct function of the amount of information at hand. This feature of the maps will appeal directly to those who are interested in exploring or selecting copper lands. For example, a given "forty" can be seen to be positively without or positively within the area underlain by the copper-bearing rocks; or it may be on or near the border line, in which case the map will give the evidence as to whether the boundary line is here located with definiteness, and the consequent probability of the given "forty's" being on the copper range.

Along the north boundary line of the copper-bearing rocks in plates VIII and IX the topography (i. e., the marked escarpment at the northern limit of the Douglas range[1]) and the intense brecciation of the traps near the contact line[2] made it possible to locate the limit of the Keweenawan traps much more carefully than the maps indicate on their faces, for these two features are not represented. However, in T. 48 N., R. 11 W., on account of the scarcity of the exposures and the lack of the marked escarpment, this boundary line is much less definitely located than elsewhere on these two maps.

[1] See II on p. 6.
[2] See p. 18.

On the county map (plate I) outside of the areas of the detailed maps the geological boundaries have been located by information obtained from different sources. The north boundary of the Lower Keweenawan in T. 46 N., R. 15 W., is taken from the maps of the former Geological Survey of Wisconsin. The southeastern boundary of the Lower Keweenawan northeast of the area shown in plate VII is not definitely located because of the lack of outcrops. The only rock exposures noted by the parties of the Survey in the vicinity of this boundary line are some knobs of coarse melaphyre in Sec. 15, T. 45 N., R. 12 W., at the "rock cut" on the C., St. P., M. & O. railway in Sec. 12 of the same township, and near the northeast corner of Sec. 31 and the southwest corner of Sec. 29, T. 46 N., R. 11 W. The boundary between the Upper and Lower Keweenawan in the southeastern corner of the county is located from the work of the former Geological Survey of Wisconsin,[1] from a map by Irving,[2] and from information kindly furnished by Prof. J. A. Udden, of Rock Island, Illinois.

On the detailed maps (plates VII, VIII, and IX) the occurrence of copper ore,—the native metal, or carbonates, or sulphides,—is indicated only in those localities where parties of the Survey have actually seen it. Copper has been reported from other localities, and farther search will undoubtedly reveal many more.

[1] Moses Strong. "Geology of the Upper St. Croix District;" Geol. of Wis., vol. III, pp. 363–428, 1880.

[2] "The Copper-Bearing Rocks of Lake Superior;" U. S. Geol. Survey, Mon. V, plate 1, 1883.

CHAPTER II.

THE ST. CROIX COPPER RANGE.

This name is applied to the belt of copper-bearing rocks which are exposed just to the northwest of the St. Croix river in the southwestern part of Douglas county. The part of this range about which we have the most information is shown on the accompanying geological map, plate VII. Outside of the area shown on this map exposures are not common except along certain parts of the Tamarack and Spruce rivers in T. 43 N., R. 15 W. A few exposures are also known in Secs. 28, 29, and 32, T. 44 N., R. 14 W., and near the south side of Sec. 6, T. 43 N., R. 14 W.

The igneous rocks here exposed are readily separable into basic lava flows of slightly varying characters and coarse melaphyres. The presence of the latter rocks make it possible to divide the area into a number of parallel belts which trend northeast and southwest. The melaphyres, on account of the greater thickness of the beds and the more resistant character of the rock, outcrop more frequently than the thinner-bedded and softer lava flows. These harder rocks commonly form low ridges, and by means of these ridges the melaphyre belts can often be traced when outcrops are very few. These ridges can be distinguished from drift ridges by their straight outlines, their uniform southwest and northeast trends, their steep northwestern slopes and their more gentle southeastern slopes. Some of the finer grained melaphyres are distinct flows, having a markedly amygdaloidal upper surface, but the nature of others is not so clear. It is not improbable that some of the coarser grained melaphyre belts are intrusive sheets, but in no case has it been possible to establish this.

SPECIAL DESCRIPTIONS.

Below are descriptions of some of the more important outcrops. The locations of all of the outcrops known in the most important part of the range can be seen by consulting the map, plate VII.

T. 46 N., R. 11 W.

The most northeasterly exposures known to the Survey on the St. Croix range are two in the S. W. ¼ of Sec. 29 (240 paces N. and 1,875 W., and 640 N. and 1,795 W.). They are of melaphyre. Near the northeast corner of Sec. 31, and extending to the north line of this section 160 paces west of the northeast corner, is a marked ridge of the same rock. This ridge runs southwest from this locality for a distance of about 400 paces, and has a precipitous northwestern face from 50 to 80 feet in height. The exposures in these two sections undoubtedly represent but one belt of melaphyre.

T. 45 N., R. 12 W.

At what is known as "the rock cut" on the C., St. P., M. and O. railway, near the center of the west side of the N. W. ¼ of Sec. 12 (1,200 paces N. and 1,850 W. to north end of cut), there is a cut extending 215 paces through a ridge of melaphyre. A few small seams exist in the rock. In one of these a very small amount of native copper was seen. Near the center of the south half of Sec. 15 (400 paces N. and 1,120 W.) is another exposure of melaphyre.

The exposures mentioned above are all that are known to the Survey in Ts. 46 N., R. 11 W., and 45 N., R. 12 W. It is very probable that all these exposures belong to one melaphyre belt.

T. 45 N., R. 13 W.

In the S. W. ¼ of Sec. 25 (50 paces N. and 500 W.) is a large exposure of melaphyre. This is a continuation of the most northwesterly belt of melaphyre shown on plate VII. On the

Moose river near the southeast corner of Sec. 14 (50 paces N. and 60 W.) is a decayed reddish trap. On the same river in the S. W. ¼ of Sec. 13 (125 paces N. and 1,700 W. and extending to 65 N. and 1,600 W.) are exposures of amygdaloidal traps.

T. 44 N., R. 13 W.

Moose River. The most southerly exposure of igneous rock on this river is on its west bank near the south side of Sec. 14 (130 paces N. and 540 W.). The rock is a fine grained, somewhat luster-mottled, amygdaloidal diabase. The amygdules contain quartz, chlorite, epidote, and calcite. In irregularly outlined areas the rock is highly charged with epidote, and in some of these areas is a small amount of native copper. The rock is cut by a few small, red flinty, vein-like forms and where these cut the epidotized areas the veins sometimes carry a little copper. This flow represents the youngest, or almost the youngest, of the Lower Keweenawan rocks in this vicinity, for just across the river occurs a conglomerate of Upper Keweenawan age.

Several other exposures occur along the river in this section; one of these (675 paces N. and 925 W.) is of much interest. It is on the west bank, near the water's edge, and consists evidently of only one flow. It is a reddish, amygdaloidal diabase, which in its coarsest parts is luster-mottled. At the southern end of the exposure is a highly epidotized part of the rock which is two feet in width, runs northeast and appears to stand in a vertical position. It can be traced for only a few feet and disappears under the soil on one side and under the water on the other. In the amygdules and cracks in this epidotized part of the rock is a considerable amount of native copper.

In Sec. 2, on the south bank of the river, is an outcrop of an amygdaloid (385 paces N. and 190 W.) which contains large porphyritic crystals of reddish feldspar. Such porphyritic amygdaloids are rare on the St. Croix range. In the same section, at a marked bend in the river, is a series of at least three highly amygdaloidal flows (580 paces N. and 750 W.). Farther up the stream in Sec. 2 on the west bank, is a low ledge (765 paces N. and 870 W.) which is poorly exposed and lies mainly under the water. The rock is a hard, dark reddish amygdaloid. The amygdules are filled by quartz, chlorite, calcite, prehnite and native copper. The ledge is about eight feet in width and seems to be copper-bearing throughout. The water rendered a careful examination of this ledge impossible. This is a favorable place for exploration, as a comparatively small amount of work would give more definite information concerning the worth of this copper-bearing layer.

Crotty Brook. Several exposures exist along this stream in Secs. 30 and 31. The most northerly exposure in Sec. 30 (1,400 paces N. and 880 W.) is on the west bank. The rock is a reddish amygdaloid and in it are a few seams and small highly epidotized areas, both of which at times carry a little native copper.

T. 43 N., R. 13 W.

Crotty Brook. The most southerly exposure of igneous rock on this stream is in the N. W. ¼ of Sec. 7 (1,420 paces N. and 1,565 W.). This is near the top of the Lower Keweenawan.[1] The rock is a reddish diabase which is distinctly luster-mottled in the center and lower part of the flow, but is amygdaloidal near the upper surface. In this amygdaloidal portion are some irregularly outlined masses of roughly spherical form and from two to ten inches in diameter. These masses appear to be parts or the ordinary rock which have been highly charged with epidote, and some of them contain small amounts of native copper. Farther up the stream, but in the same quarter section, are other exposures of amygdaloid cut at times by small vein-like forms of reddish, hard, flinty rock which occasionally carries small specks of copper. In one of these amygdaloids (1,880 paces N. and 1,720 W.) is an oval mass of the rock which is rich in epidote. As exposed this mass is ten inches wide and fifteen inches long, but more of it evidently exists under the water. In the amygdules of this mass of rock metallic copper is abundant.

[1] See p. 16.

At the Copper mine dam on Crotty brook, in the S. W. ¼ of Sec. 6, three pits were sunk perhaps thirty years ago. The rock thrown out is a fine grained reddish diabase with amgydules of chlorite and quartz. Some of the rock is rich in epidote. None of the material examined showed any copper, although it is not unlikely that this mineral occurred in the epidotized parts of the rock and thus attracted exploration at this place. This is the only locality on the St. Croix range where any serious prospecting for copper seems to have been carried on.

T. 44 N., R. 14 W.

The only exposures noted in this township outside the area shown in the geological map (plate VII) are in Secs. 28, 29, and 32. In the last section (400 paces N. and 1,505 W.) is a ridge of medium grained reddish diorite, which is in places slightly porphyritic with feldspars. This rock contains a few metallic-appearing particles which might be mistaken for copper, but which are of some micaceous mineral that has developed in the alteration of the rock. Similar rock, most probably of the same mass, occurs to the southwest (15 paces N. and 1,845 W.) in the same section and also forms a prominent ridge which runs northeast and southwest through the center of Sec. 28.

In the N. W. ¼ of Sec. 29 are three exposures of melaphyre. These are near the east bank of the Tamarack river and a short distance above the buildings at the Tamarack farm.

T. 43 N., R. 14 W.

There are many exposures of melaphyre in this township and a number of amygdaloids in Secs. 2, 11, and 16. In the last section (260 paces N. and 1,040 W.) is an outcrop of amygdaloidal porphyry very similar to the porphyry noted on the Moose river in Sec. 2, T. 44 N., R. 13 W.[1] The two outcrops are in about the same stratigraphic position and perhaps represent one flow.

On the south line of Sec. 22, (1,235 paces west of the southeast corner of this section) is an exposure of reddish amygda-

[1] See p. 27.

loid which has epidote, chlorite and abundant calcite in the amygdules. Some malachite, which is undoubtedly an alteration product from native copper, occurs in these amygdules.

T. 43 N., R. 15 W.

Along the Tamarack river in Secs. 10, 15, 16, 20, 21, and 29 are a number of exposures of amygdaloidal rocks. Similar rocks occur on the Spruce river in Secs. 8 and 17. On the east bank of the former stream in Sec. 16 (about 795 paces N. and 900 W., and extending for 50 paces down stream) is some hard reddish diabase with amygdules holding chlorite, calcite and quartz. In some of the amygdules is also metallic copper. The coarser parts of the rock show luster-mottling. Farther down the river in the same section are four other outcrops, the most southern (400 paces N. and 1,130 W.) of which is of rock similar to that just mentioned. Here a small piece of native copper was found in one of the amygdules.

In Sec. 29 three exposures of melaphyre occur on the east bank of the Tamarack river. These probably belong to the same layer, which is quite likely the southwestern continuation of the layer exposed in three places in Sec. 29, T. 44 N., R. 14 W., mentioned above.

T. 42 N., R. 15 W.

Along Chases brook in Secs. 9 and 16 are some interesting exposures. In the latter section (1,840 paces N. and 1,050 W.) is a mass of coarse melaphyre forming a barrier across the stream. The augite crystals in this rock are at times an inch in diameter. Further up the stream in Sec. 9 (1,479 paces N. and 537 W. and extending northward to the north line of this section) are a series of amygdaloidal rocks. In the upper part of several of these flows native copper occurs.

CHAPTER III.

THE DOUGLAS COPPER RANGE.

This name is applied to the belt of copper-bearing rocks which are exposed along the hill range that marks the northern limit of the Lower Keweenawan rocks in Douglas county. The most important parts of this range are shown in detail on the accompanying geological maps, plates VIII and IX. Outside of the area of these maps there are very few rock exposures. Along this hill range to the east of Douglas county no outcrops of the traps have been reported, while to the west of this county some outcrops occur in Minnesota.

In some particulars the rocks of the Douglas range differ from those of the St. Croix range: (1) Prehnite is much more common on the former than on the latter. (2) The melaphyre belts, which are so characteristic a feature of the latter range, are lacking on the former, although there are in a few places rocks which approach rather closely to the typical melaphyres of the southern range. (3) On the Douglas range intrusive rocks are in places abundant, while they are practically lacking on the St. Croix range, unless some of the melaphyre belts should prove to be of this nature. These intrusive rocks consist of diabases, gabbros, granites, and syenites. The gabbros and syenites, which approach the gabbros in composition and which may be parts of the same general magma, are the most common of these intrusive rocks. On the west the intrusive rocks were first noticed at Pilot mound in Sec. 15, T. 47 N., R. 13 W. East of here they occur in abundance along the Aminicon river in many places between Rockmontand the southern limit of the Lake Superior sandstone. Some of the intrusive rocks are seen along the Middle river, especially in Sec. 2, T. 47 N., R. 12 W., and a bold knob of gabbro and associated rocks exists in the northern part of the N. W. ¼ of Sec. 25, T. 48

N., R. 12 W. The more acid of these intrusive rocks (granites and syenites) are in general of later date than the gabbros.

The strike of the lava flows on the Douglas range is northeast and southwest toward the western end. On going eastward the strike gradually becomes more nearly east and west, and at the eastern part of the range has this latter direction. The strike is approximately, but not exactly, parallel to the fault line which separates the traps from the Lake Superior sandstone to the north, the direction of the fault averaging a little more nearly east and west than does the strike which is inclined more toward the east-northeast and west-southwest. Thus in going from the eastern end of the range towards the west, one passes over lower and lower, and consequently older and older, flows.

SPECIAL DESCRIPTIONS.

Serious prospecting for copper has been carried on in the rocks of the Douglas range at intervals for over fifty years, and there are indications of some prehistoric attempts at copper mining. The history of these explorations has already been published by the Wisconsin Survey,[1] and the present preliminary report does not attempt to duplicate these descriptions. Below will be found brief accounts of the various locations where explorations for copper have recently,—mostly in 1898 and 1899,—been carried on.

The Culligan Location.

Explorations at this place have been made in the S. W. ¼ of Sec. 29, the S. E. ¼ of Sec. 30 and the N. E. ¼ of Sec. 31, T. 47 N., R. 14 W. In Sec. 30 the most work has been done and here are four test pits, which were filled with water when the examination was made. The pits are located along a small creek near the southeast corner of this section. One pit is reported to be thirteen feet in depth, the lower three feet being in rock. Another one is also thirteen feet in depth, while another is thirty feet deep, the lower seventeen being in rock. The material thrown out of these pits is all highly brecciated and some

[1] E. T. Sweet. Geol. of Wis., vol. III, pp. 353–362, 1880.

of it shows slickensided surfaces. On some of this material there are greenish stains which resemble malachite. These pits are regarded as located near the junction of the traps and the Lake Superior sandstone.

In Sec. 29 (770 paces N. and 1,150 W.) a shallow trench has been dug and the rock thrown out is mainly a greenish gray, hard amygdaloid. The amygdules are small, but numerous, and most of them contain quartz. Many of the amygdules hold native copper. Water in the trench prevented a careful examination. The copper-bearing belt of rock is reported to be five feet in width. If the rock thrown out is a fair sample of this belt,—and such seems to be the case,—this flow ought to be prospected more fully.

Along the creek in the N. E. ¼ of Sec. 31 there are exposures showing several flows which in some places carry copper both in the amygdaloidal parts of the rock and in small veins. The bed richest in copper has been struck in a test pit (1,697 paces N. and 113 W.) which passes through about four feet of hard, greenish brown. barren rock and then strikes an amygdaloid rich in epidote. This last rock carries considerable native copper. Many of the amygdules are completely filled with the metal, which also occurs in small seams. The exploration has not been carried far enough to determine how extensive this copper-bearing rock is, in fact the amygdaloid which carries the copper has been penetrated for only a few inches. The locality was visited again later in the season, but practically no more work had been done. This copper-bearing flow, like that mentioned above, ought to be exploited more fully. A little more work would determine whether the parts already exposed were fair averages in copper content or were richer or poorer than the rest of the copper-bearing amygdaloidal portion of the flow. And at the same time the thickness and probable extent of the copper-bearing rock could be determined. These prospects in Secs. 29 and 31 are more encouraging than those in Sec. 30, where most of the work has been done on this property.

The Copper Creek Location.

This property includes the S. W. ¼ of Sec. 14 and the S. E. ¼ of Sec. 15, T. 47 N., R. 14 W. In former years considerable work was done here and several test pits and shafts were sunk and strippings made in the vicinity of the junction of the two branches of Copper creek. Unfortunately the information gained by this work has been lost, or is not available. During 1899 work was resumed again, mainly in different places from the old work.

Near the junction of the creeks there is a series of flows which strike approximately northeast and southwest. The dip is from 54° to 62° towards the southeast. The flows have amygdaloidal upper parts and in several cases, at the junction of two flows or in the upper part of a flow, are fractures whose dip correspond with the dip of the flows. Commonly along the fractures there is some brecciation. The broken parts of the rock are cemented by vein material,—quartz, calcite and prehnite,—and it is in this vein material that most of the copper occurs, although it is also found in the amygdules.

On the main stream, south of the junction, several flows are seen. In the upper part of one of these (159 paces N. and 43 W., Sec. 15) and the lower part of the next upper flow native copper occurs in amygdules. The copper-bearing bed is about a foot in thickness. On the high ground between the two creeks and south of their junction is a pit (233 paces N. and 41 W., Sec. 15) which is perhaps 50 feet in depth, but now is, like all the others, filled with water. The pit slopes at an angle of 60° towards the south-southeast. To the northeast is a trench running along the junction between two flows,—probably along the lower side of the flow in whose upper surface is the pit just mentioned. Thrown out of the pit or trench is a quantity of rock which can be termed copper ore. It is brecciated rock cemented by quartz, calcite, prehnite, and some native copper. The brecciation is evidently along a fracture between two flows, for the rock is in part the dense fine grained portion from the base of a flow and in part the porous amygdaloidal portion of the top of a flow.

To the east of the main creek and north of the junction of the streams are several pits and in one place a tunnel. From what can now be seen these pits do not show as encouraging prospects as that just mentioned.

On the west side of the main stream, just north of the junction of the two streams, is a perpendicular rock face which has been exploited recently. The rock is in many places brecciated and along the broken sides of the fragments are slickensided surfaces. In some very irregular and limited areas the brecciation is more intense and the broken rock is cemented by nearly pure white calcite, and in this calcite is some native copper in the form of fine wires,—averaging less than a thirty-second of an inch in thickness. In addition to the calcite there is here also quartz and prehnite, both in amygdules and in fissures. The copper here is not so abundant as at the pit described above.

On the eastern of the two creeks there are a number of exposures, and at one of these (245 paces N. and 1,900 W., Sec. 14) is a brecciated belt which appears to be parallel to the dip. This belt is from one and a half to two feet in width and consists of rock fragments cemented by vein material, which here is mainly quartz and prehnite. The exposure is near the bed of the stream, and above this belt of broken rock is a highly epidotized area, evidently of the same flow. In the vein material is native copper, commonly in wire-like forms; these wires appear to be coated by native silver.

Later in the season this locality was visited again; the vein had been uncovered for a distance of thirty feet. It retained an approximately uniform width,—one and a half to two feet,—but was not as rich in copper as in the place where it was first uncovered.

On the northern brow of the high hill in Sec. 15 (480 paces N. and 500 W.) a pit has been sunk along the top of an amygdaloidal flow. The rock is a brown-weathering, reddish diabase. The south wall of the pit is the bottom of the next overlying flow. The strike and dip at the pit are rather anomalous, the former being N. 30° E. and the latter 78° towards the south of this. In this immediate vicinity a chance was had to measure the strike and dip along a larger distance than could be obtained at the pit; the strike is N. 20° E. and the dip averages 70° towards the south of this. The upper three feet of the flow exposed in this pit contain most of the ore, although it occurs in smaller amounts through a thickness of twelve feet. The ore consists of two metallic minerals which have altered considerably. One of these is of a silver white color but has largely changed to a rusty brownish material. In the field this mineral was thought to be a nickel sulphide. The other mineral is regarded as a copper sulphide now almost completely changed to the green carbonate, malachite, which not only occurs in the amygdules but also exists as green stains along cracks. This pit is in similar rock, and near the same horizon stratigraphically, as another pit which was sunk for nickel several years ago about half a mile farther northeast (935 paces N. and 1,790 W., Sec. 14).

The Fond du Lac Location.

Prospecting at this location has been carried on in the N. E. ¼ of Sec. 8, T. 47 N., R. 13 W. In former years two deep pits were sunk here, called the Stewart and the Parker shafts. The former is about 400 paces northeast of the latter. In 1899 a considerable amount of stripping was done on this property, and several shallow pits and trenches were made in the rock. This work was of such a nature as to expose a large surface of the copper-bearing amygdaloids; in fact the work here has resulted in an examination of a larger amount of rock in which copper might occur than at any other of the recent explorations on the Douglas range.

At the brow of the hill range, crossed by the road on the east line of Sec. 8, is an exposure of hard, reddish, flinty rock which has been much fractured. The fractures are frequently healed by calcite. This exposure is 245 paces south of the northeast corner of Sec. 8, and other exposures of the same rock occur both to the west and to the east. About 100 paces west of the road a cross cut has been made from the rock just mentioned south for 100 paces across some amygdaloidal flows.

Trenching at the Fond du Lac Mine. N. E ¼ Sec. 8, T. 47 N., R. 13 W.

The Stewart shaft (1,400 paces N. and 345 W.) is said to be 65 feet deep. At the time the Survey parties examined it, it contained water to within about 25 feet of the top. The shaft goes down along a vein-like mass of rock which dips southward at an angle of 35°. The country rock is here a medium grained reddish diabase and the rock of the vein-like mass is a coarser grained diabasic rock which has been highly charged with epidote. The latter rock at the shaft varies from 10 to 18 inches in thickness. It can be traced, as exposed in strippings, almost continuously for 100 paces to the east of the shaft and for 200 paces to the west. Towards the east it becomes smaller and where last seen is about six inches in thickness. This vein-like mass appears to be a sheet of igneous rock which has been intruded along a fissure in the country rock, the fissure practically coinciding in direction with the dip and strike of the inclosing rocks. The copper content of this rock varies considerably at different points; in some places no copper at all is seen, at others this metal is quite abundant.

The flow, in which is the vein-like mass of rock just described, is markedly amygdaloidal at its upper surface. About 200 paces west of the Stewart shaft a cross cut has been made from this flow south for over 100 paces. One of the rocks struck in this cross cut is a melaphyre which approaches in coarseness and general characters the characteristic melaphyres of the St. Croix range. Near the north end of this cross cut, and apparently in the upper part of the same flow, in which is the Stewart shaft, is a test pit. Here the amygdaloidal upper part of the flow has a horizontal breadth of about 18 feet. Pieces of sheet copper are reported from this place. These occur in seams in the rock, the seams being parallel with the dip. The specimens from this place seen by the writer were about one-eighth of an inch in thickness and from two to three inches across. This amygdaloidal layer is known as the Admiral Dewey vein or lode.

The Parker shaft (1,060 paces N. and 520 W.) is said to be 80 feet in depth. It goes down on the junction between two flows and slopes 22° to 38° toward the south. The plane of division between the two flows is the foot wall of the shaft, as nearly as could be seen, the shaft being practically full of water when the examination was made. The upper part of the lower flow here is amygdaloidal, the amygdaloidal portion being ten to twelve feet in thickness. At the shaft and just to the west, where some trenching has been done, this amygdaloid carries copper. The upper flow at the shaft is also amygdaloidal and at one place (1,010 paces N. and 615 W.) west of the shaft a trench has been cut across the amygdaloidal part, which here has a horizontal width of 18 feet. (See plate X.) This is known as the Little Maude vein. In places the amygdaloid has been fractured, probably along a plane parallel with the surface of the flow, and the fractures have been filled with quartz, prehnite, calcite, and epidote. With these minerals is considerable native copper, which has partly altered to malachite. Small nuggets of copper, weighing several ounces, are reported from this place.

To the south of this one or two other flows have been uncovered; they bear copper in small amounts, but not as much as occurs in the Little Maude vein.

The Catlin Location.

In the S. E. ¼ of Sec. 34, T. 48 N., R. 13 W., some exploratory work has been done. This consisted of blasting in a few places and the sinking of two test pits. One of these is on the St. Croix road (590 paces N. and 120 W.) and strikes the upper part of a porphyritic amygdaloid. The other (50 paces N. and 620 W.) is on a small stream. The rock here is a reddish medium grained diabase.

The Starkweather Location.

This property has been known as the Edwards mine and also as the Wisconsin mine.[1] It is situated in the N. W. ¼ of Sec. 2, T. 47 N., R. 13 W. In the N. W. ¼ of this quarter section several pits, or shafts, have been sunk. During the time the Survey parties were in this district there was no work being done at this locality, and the pits were full of water. Consequently no careful examination could be made. It is evident that the

[1] E. T. Sweet. Geol. of Wis., vol. III, p. 360, 1880.

property is crossed by a series of amygdaloidal flows and that some of these are copper-bearing. The rock thrown out of the pits is in general of four kinds: (1) dense diabasic rock evidently belonging to the base of a flow; (2) amygdaloid from the upper part of a flow; (3) fine grained, vein-like material, probably acting as a cement to the broken up upper surface of a flow; (4) brecciated rock cemented by vein material which is mainly quartz, calcite, epidote, and a red mineral (probably laumontite). Native copper, altered in places to malachite, occurs in the amygdules, and also in the vein cement of the brecciated rock, but more commonly in the latter. Most probably the richest specimens of the copper-bearing rock have been taken away by people who not uncommonly visit this location. Nothing can be said, from the examination it was possible to make, concerning the thickness and richness of the copper-bearing rock. The general relations and manner of occurrence of the copper appear to be the same as in the other localities already described.

The Aminicon Location.

This is situated in the N. W. $\frac{1}{4}$ of Sec. 11, T. 47 N., R. 13 W. Some stripping and blasting have been done along the bold rock hill that extends northeast and southwest through this quarter section. The most serious work was done in sinking a test pit (1,625 paces N. and 1,110 W.) at the base of this hill near its northeastern end. This pit goes down on a small vein, which is from one-fourth to two inches in width. It has slickensided surfaces and is filled mainly with calcite, quartz, talc, and soft clay selvage. The vein strikes nearly east and west and dips 75° to the north near the surface, but the dip varies to more nearly vertical a few feet below the surface. It is the expectation of the owners that this vein will widen out and become copper-bearing some feet below the surface.

Just to the north of this pit is an irregular vein, from two to eighteen inches in width. It is about vertical, strikes north and south and towards the south splits into two veins. The vein is a brecciated portion of the rock cemented by quartz, calcite and red feldspar. There is also chalcopyrite, chalcocite and malachite in the vein. The latter is most probably secondary, possibly after native copper, which is reported from this vein. Chalcopyrite and chalcocite also occur in amygdules in several places along this hill.

The North Wisconsin Location.

This property is located in the S. W. ¼ of Sec. 3 and the N. W. ¼ of Sec. 10, T. 47 N., R. 12 W. The outcrops noted at this place and the prospecting done are confined to the immediate vicinity of the line between these sections and do not extend over 200 paces eastward from the west corner post on this line.

Along the Middle river, just below the dam, are exposures of several flows which are markedly amygdaloidal in the upper parts, the amygdules being frequently of laumontite. Here, on the east side of the river, a pit has been sunk. This is said to be 51 feet in depth and has drifts running from the bottom. In these drifts considerable copper has been reported. At the time this property was examined the pit was full of water. On the west bank of the river is a vein-like form, six inches wide, cutting one of the flows. The vein rock is hard, very fine grained, and greenish to yellowish in color. It contains specks of native copper and there are malachite stains along the cracks.

A shaft (22 paces N. and 1,853 W., Sec. 3) is being sunk in one of the flows. This is east of the dam, and just to the south of the shaft are three pits full of water. The shaft slopes about 62° to the south. It is seven and a half by twelve feet, inside the timbers, and in August, 1899, had reached a depth of about 80 feet. At this time machinery for hoisting and drilling was being put in. (See plate XI.) The shaft goes down in the amygdaloidal upper part of a flow, and this rock carried native copper in the amygdules, although not so abundantly as reported from the pit, mentioned above, on the east bank of the river.

The Astor Location.

No extensive work has been done on this property, which is in the N. W. ¼ of Sec. 28 and the N. E. ¼ of Sec. 29, T. 48 N., R. 10 W. In the former section (1,275 paces N. and 1,820 W.)

The North Wisconsin Mine. S. W. ¼ Sec. 3, T. 47 N., R. 13 W.

is a pit which at the time of the examination had not certainly reached the solid bed rock, although very close to it. The material thrown out was practically all of one rock which had been brecciated and cemented by vein minerals. About 150 paces north of this pit and at a little falls on a small stream is an exposure which shows evidence of having been explored a number of years ago, and just to the north of it is a filled test pit. The rock here shows an epidotized area, two to four feet in width. In this, and in cracks adjoining, is chalcopyrite, and native copper is also reported.

To the west in Sec. 29 there are a number of exposures, usually of amygdaloidal rock which bears chalcopyrite. In one locality there seems to be evidence of some very ancient attempts at prospecting, the ground now being covered by large trees which have grown up since this was done.

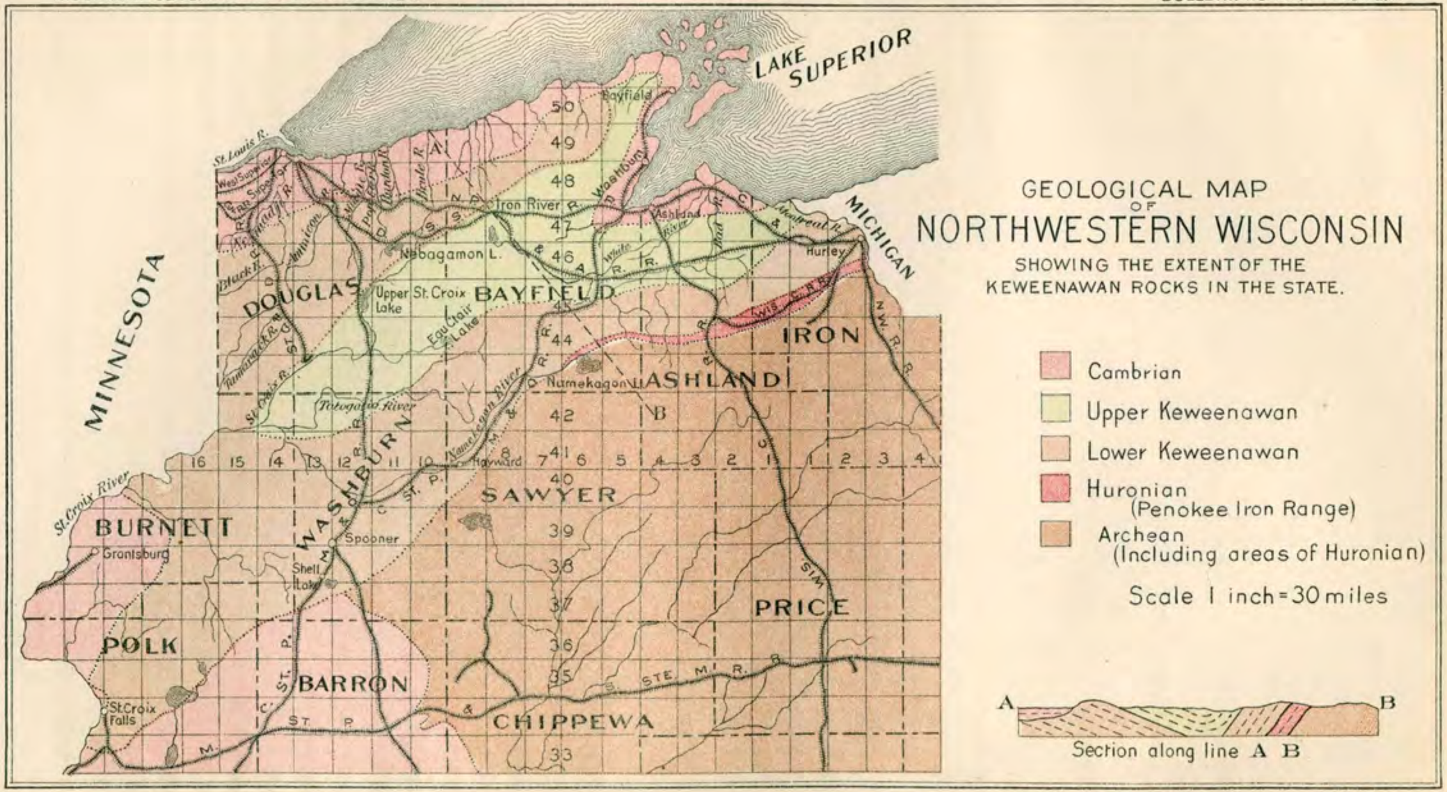
The Percival Location.

The principal explorations on this property have been in the N. ½ of S. W. ¼ of N. E. ¼ of Sec. 27, T. 48 N., R. 10 W. Considerable work was done here a number of years ago, and work has been actively resumed recently.

An old pit (1,303 paces N. and 1,110 W.) west of the present shaft goes down perhaps 30 feet. The pit was sunk to investigate a vein which trends nearly east and west. The vein is from one to ten inches in width and is mainly of calcite. It carries some native copper. Just to the east of this is a stripping which exposes the same vein. Prospecting on at least two veins of similar character, also carrying copper, has been done in several places a short distance east of this pit. One, at least, of these veins differs from the other veins met in the explorations already described in that it is not parallel to the dip and strike of the beds of igneous rock in which it lies. This vein dips to the north at an angle of about 65°, while the dip of the flows is toward the south. It is not unlikely that the other veins at this locality also fills fractures which do not lie parallel with the surface of the flows.

The principal work at this locality is now being done at a shaft (1,423 paces N. and 722 W.) which is eight by six feet in size. Drilling, hoisting, and pumping at this shaft are done by steam, this being the only locality on the Douglas range where machinery was used during the summer of 1899. The shaft goes down in the amygdaloidal part of a flow, and the hanging wall of the shaft is the bottom of the next higher flow. The dip of the upper part of the shaft is about 40° towards the south, but towards the bottom it becomes steeper, being 46°. In Auggust, 1899, the shaft had reached a depth of 90 feet. The amygdaloid penetrated by this shaft contains the minerals common to the amygdaloids of the district, but is noticeable for the laumontite and the large amount of prehnite. This rock is in places highly charged with epidote, the masses rich in this mineral being, as far as can be seen, roughly spherical in shape. Several of these epidotized masses have been found in the shaft. These areas vary in size, but the writer did not see evidence that any of them yet found here are over six feet in diameter. It is in these highly epidotized masses that the chief part of the copper occurs, and at times specimens from such parts of the rock are very rich in this metal, which occurs in the amygdules, in cracks and in irregularly disseminated particles.

About 200 and 400 paces east of this shaft are pits probably sunk on the same flow. At each the amygdaloid contains considerable quantities of laumontite. Some stripping has recently been done on a small stream about a quarter of a mile northeast of the shaft.


GEOLOGICAL MAP
OF
NORTHWESTERN WISCONSIN
SHOWING THE EXTENT OF THE
KEWEENAWAN ROCKS IN THE STATE.
Cambrian
Upper Keweenawan
Lower Keweenawan
Huronian
(Penokee Iron Range)
Archean
(Including areas of Huronian)
Scale 1 inch = 30 miles
Section along line A B
LAKE SUPERIOR
MINNESOTA
MICHIGAN
DOUGLAS
BAYFIELD
ASHLAND
IRON
BURNETT
WASHBURN
SAWYER
PRICE
POLK
BARRON
CHIPPEWA
Bayfield
Iron River
Nebagamon L.
Upper St. Croix Lake
Eau Claire Lake
Ashland
Hurley
Namekagon L.
Hayward
Spooner
Shell Lake
Grantsburg
St. Croix Falls
St. Louis R.
St. Croix River
Totogatic River
Namekagon River
White R.
Montreal R.
Bad R.
Brule R.
West Superior

CHAPTER IV.

THE MINONG COPPER RANGE.

The name Minong copper range is here applied to the northward dipping belt of copper-bearing or Lower Keweenawan rocks which enters Wisconsin, from Michigan, at the Montreal river a few miles south of lake Superior and extends westward and southwestward through Iron, Ashland and Bayfield counties and into Washburn county. Along this distance the outcrops of Keweenawan traps are common, but southwest of T. 42 N., R. 11 W., Washburn county, they are not common, the rocks being in most places entirely covered by the drift. These rocks extend, however, southwestward to and beyond the western border of the state at St. Croix Falls, Wisconsin, and Taylors Falls, Minnesota. Along the eastern part of its extent, in Iron and Ashland counties, this range of rocks is frequently known as "the copper range" in distinction from the Penokee iron range, which lies just to the south and is parallel with the copper range.

INTRODUCTION.

The part of this range studied in detail, and which is here reported on, extends from the west side of T. 42 N., R. 11 W., northwestward to the east side of T. 45 N., R. 6 W. This area is about forty miles in length (northeast and southwest) and from four to six miles in width. It includes the most important parts of the copper-bearing rocks in Washburn and Bayfield counties, except for a distance of six miles on the east side of the latter county. A considerable part of the area studied in detail is shown on plate XIII.

The field work on this district was done in July and August, 1900. In this work the writer was assisted by Mr. H. M. Adkinson, of the University of Chicago, and by Mr. H. F. Little, of Northwestern University. Messrs. J. L. Goodvin, E. Goodvin, and B. Goodvin, of Minong, and during a part of the season Mr. Charles Blaisdell, of Drummond, acted as compassmen. Mr. J. L. Goodvin was very familiar with the district and had already partially traced out certain of the belts of rocks, especially the conglomerates. The field work was carried on in the manner already indicated.[1]

The most important papers dealing with that part of the Minong range here considered are those by Messrs. Chamberlin, Irving, and Strong already cited.[2]

GEOLOGY OF NORTHWESTERN WISCONSIN.[3]

The rocks of northwestern Wisconsin are divided in the following manner, the oldest being placed at the bottom:

Cambrian	Lake Superior sandstone.		
Algonkian	Keweenawan	Upper.	Conglomerates, sandstone and shales.
		Lower.	Traps and conglomerates.
	Huronian	Upper.	Rocks of the Penokee iron range.
		Lower.	
Archean	Granites, gneisses, greenstones and various schists.		

The oldest rocks, the Archean, are granites, gneisses, greenstones, and schists of various kinds. They occupy a large tract of country to the south of the later rocks. Lying unconformably above the Archean are the rocks of the Lower Huronian, which in this part of the state are represented only by a belt of limestone at the base of the Penokee iron range. This limestone dips at a high angle to the north. The Upper Huronian, represented by the rocks of the Penokee iron range, lies unconformably upon the older rocks. Strata of this age enter the state at the Montreal river and extend in a narrow band west-

[1]Page 2.
[2]Page 5.
[3]See the geological map of northwestern Wisconsin, plate XII.

ward and southwestward to the vicinity of Numakagon lake. The dip is at a high angle to the north, or north-northwest. The rock are quartzites, slates, and schists of several varieties. The Lower Keweenawan rocks, composed essentially of traps with a few bands of conglomerates, lie next above the Upper Huronian strata, but are separated from these by an unconformity. These Lower Keweenawan or copper-bearing rocks lie along the north side of the Penokee range and beyond this range extend southwestward in a broad band to the Minnesota line, where they swing around to the north and run through Douglas county and into Bayfield county. Immediately and conformably overlying the Lower Keweenawan are the conglomerates, sandstones, and shales of the Upper Keweenawan. While unconformably above all and lying in a practically horizontal position is the Lake Superior sandstone, which skirts the shore of the lake from its western end eastward almost to the mouth of the Montreal river.

The structure of this part of the state is that of a great syncline. The rocks on the south side of the syncline dip toward the north or northwest, while those of the north side dip toward the south or southeast. This is the syncline which forms the main part of the basin of lake Superior, but in Wisconsin the synclinal rock basin runs farther south than does the western part of the lake basin. The section on plate XII shows this synclinal structure, the rocks of both the Huronian and the Keweenawan, but not those of the Cambrian, taking part in this structure. At the southwestern end of this synclinal basin the rocks swing around the end of the basin in the same manner that the two sides of a spoon come together at the end of the spoon.

THE LOWER KEWEENAWAN.

The rocks of the Minong copper range are the direct westward continuation, both geographically and geologically, of the copper-bearing rocks of Keweenaw point. They are also unquestionably continuous, beneath the surface, with the rocks of the St. Croix range. They differ, however, from those of the latter range in two important particulars: first, in the presence of beds of conglomerates, and second, in the presence toward the eastern part of the range of masses of coarse grained granitoid rocks—gabbro and granite.

Sedimentary Rocks.

In that part of the Minong range thus far studied in detail there are at least four beds of conglomerate, which, beginning with the lowest, may be designated as the first, second, third and fourth conglomerates.[1]

The first conglomerate.[2]—Only one outcrop of this conglomerate is known. This is on the Totogatic-once creek in the northwest quarter of section 8, T. 43 N., R. 9 W., just below (north of) the High dam. The conglomerate bed is two feet and three inches in thickness and can be traced for a distance of about twenty-five feet along the hillside on the east bank of the creek. The pebbles are well rounded and of all sizes up to four inches in diameter, but most of them are under two inches in diameter. They are in general more acid than the rocks seen to the south, but no marked quartz-porphyry pebbles were seen; there are, however, a few pebbles of red syenite. In the base of the conglomerate are a few malachite stains. The conglomerate is overlain by a heavy flow of coarse grained melaphyre and is underlain by a finer melaphyre. The upper part of the latter flow is broken up and cemented by plastic material.

The second conglomerate.—This has been seen in a number of places, but the most extensive exposures are along Black creek in Secs. 5, 7, and 8, T. 42 N., R. 10 W., and Sec. 13, T. 42 N., R. 11 W. In fact, this stream flows for several miles in a valley cut in this conglomerate. Other good exposures occur near Dingle creek in the northeast quarter of Sec. 13, T. 43 N., R. 10 W. The pebbles of this conglomerate, as seen along Black creek, are well rounded and are of all sizes up to five inches in diameter and sometimes even larger. They are of

[1]For location of these conglomerates see the geological map, plate XIII.

[2]The discovery of this conglomerate is due, as far as the writer knows, to Prof. J. A. Udden of Rock Island, Illinois, who saw it in the summer of 1899.

various kinds of igneous rock, but in general are more acid than the rocks exposed to the southeast. Quartz-porphry pebbles are not common, but those of red syenite are rather common.

With the conglomerate are beds of reddish brown and yellow sandstone,—the yellow color being due to the abundance of epidote,—and some bands of red shale. These beds of finer material are more abundant in the lower half of the conglomerate belt; in fact in some places the lower part of this belt is made entirely of the sandstone and shale, and it is in this softer material that the valley of Black creek lies.

This conglomerate is overlain by a flow of melaphyre that can usually be distinguished from the other flows of melaphyre. It is commonly very fresh and the luster mottlings are very sharply defined and not quite as abundant as is commonly the case. In the base of this melaphyre copper has been found in a number of places, especially at the Mudge location, and the copper also occurs in the conglomerate, though, as far as known, in less amount than in the melaphyre. The flow underlying this conglomerate is a coarse melaphyre, which frequently has a reddish cast. The upper part of this flow is markedly amygdaloidal, and in places small amounts of copper occur in the amygdules. The extreme upper part of the flow is noticeably scoriaceous and has been broken and the fragments more or less separated from each other. In between the fragments, and also in cracks which run down into the flow for a few inches, is a fine reddish to gray detrital material, and this is seen, at least in one place, to be nothing but the lower part of the fine sediments of the conglomerate belt. This feature, i. e., the fragmental upper part of the flow cemented by detrital material, is of not uncommon occurrence and in the field note-books was termed "the broken up upper part of a flow." Wherever the uppermost part of the flow immediately underlying this conglomerate is exposed, it presents this peculiar appearance.

By means of (1) actual exposures, (2) a depression in the area underlain by the softer parts of the conglomerate belt, (3) the peculiar overlying flow of the melaphyre and (4) the underlying melaphyre with its peculiar broken up upper part, this conglomerate belt can be traced from the west side of Sec. 28, T. 42 N., R. 11 W., northeastward to where it crosses the Totogatic-once creek in Sec. 5, T. 43 N., R. 9 W. Northeast of this locality the conglomerate has not been traced, but it is probable that the exposure of conglomerate on the north side of the road at the west edge of Sec. 33, T. 45 N., R. 8 W., belongs to this same belt. The conglomerate at this locality contains numerous quartz-porphyry pebbles, which are sometimes nearly a foot in diameter. It is overlain, as exposed in one place, by three feet of a brecciated reddish amygdaloid cemented largely by calcite and quartz. Overlying this is a melaphyre very similar in appearance to that which immediately overlies the second conglomerate.

The third conglomerate.—This is known only from the test pits at the Montrose location in the northwest quarter of Sec. 12, T. 44 N., R. 9 W. The chief pebbles of this conglomerate are quartz-porphyry, and it has below the coarse material some layers of sandstone similar to the finer layers of the second conglomerate. (For further notice of this conglomerate see the description of the Montrose location, pages 57–59.)

The fourth conglomerate.—The only known exposure of this conglomerate is in the northwest quarter of Sec. 28, T. 44 N., R. 9 W. The pebbles are well rounded and are of all sizes up to a foot in diameter. Nine-tenths of them are of quartz-porphyry; besides these there are pebbles of fine grained, sometimes amygdaloidal trap and rarely one of vein quartz. The matrix of the conglomerate is scarce, there being only a few areas which are not crowded with pebbles. A thickness of about twenty-two feet of this conglomerate is exposed, and below this, judging from the presence of loose slabs of rock, is some sandstone.

Immediately overlying the conglomerate is a flow of porphyritic amygdaloidal diabase. The porphyritic feldspars weather white, and are usually from one-fourth to one-half inch in length, but sometimes are one and a half inches long. The amygdules are not numerous and are mostly of quartz.

In addition to the exposure already mentioned the location of this conglomerate is known from exposures of the overlying porphyritic diabase in the southeast quarter of Sec. 21 (845 paces N. and 625 W.), T. 44 N., R. 9 W., and at the Montrose location in the northwest quarter of Sec. 12 of the same township. At the last place the presence of the conglomerate is also known from a test pit. Along the south bank of the Totogaticonce creek in the western part of Sec. 12 and the eastern part of Sec. 11, T. 43 N., R. 10 W., are many boulders of a conglomerate similar to this. In fact nine-tenths of the boulders at this place are of conglomerate. It seems quite probable that the fourth conglomerate here underlies the stream.

Other conglomerates.—Possibly another conglomerate has already been mentioned under the second conglomerate. On the Numakagon road near the northeast corner of Sec. 10, T. 44 N., R. 6 W., and in the immedite vicinity are exposures of conglomerate. This contains a few malachite stains and has evidently been metamorphosed to a greater or less extent by the gabbro which occurs immediately to the north. The relations of this conglomerate to those described above are not known. Conglomerate also occurs at the Bayfield location in the northwest quarter of Sec. 6, T. 44 N., R. 5 W., but its relation to other belts of conglomerate has not been ascertained.

Igneous Rocks.

The igneous rocks of the Minong range are remarkably similar to those of the St. Croix and Douglas ranges. In fact there is an absolute identity of lithological characters on the St. Croix range and on the western part of the Minong range, except for the presence of interbedded conglomerates on the latter range. The most noticeable igneous rocks of each of these two ranges are the melaphyres which are the coarsest grained and the hardest, and consequently the most numerous, rocks of the exposures. The distribution of these belts of melaphyres is shown in part on plate XIII, but east of the limits of this map the melaphyre becomes less common and even very rare. This is not due entirely to absence of exposures, but also to the fact that these flows do not exist in much force in this area.

It has been suggested that some of the belts of coarse melaphyres of the St. Croix range might be of an intrusive nature,[1] but a study of the melaphyre belts of the Minong range does not strengthen this supposition. As far as the upper parts of these belts were studied, all, even the coarsest, show the characters of surface flows rather than of intruded sheets.

Gabbro, which is not known on the St. Croix range but is on the Douglas range, also exists on the Minong range, here forming a wide belt of rock at the base of the Keweenawan and running from T. 45 N., R. 6 W., almost to the Montreal river. Most of the area underlain by this rock is beyond the limits of the district covered by detailed field work. Near the eastern edge of T. 45 N., R. 6 W., the gabbro is seen in several places. It occurs in contact with a conglomerate which has been metamorphosed by the gabbro[2] and it presents many of the features shown by the great gabbro mass at the base of the Keweenawan of northeastern Minnesota.[3] In fact this rock is Wisconsin appears, like that in Minnesota, to have been intruded in the form of a laccolite into the adjoining strata and to have metamorphosed these strata, especially when they were sedimentary rocks, as in the case of the conglomerate just mentioned and the sediments of the Penokee iron range.

In addition to the coarse grained rocks just mentioned (melaphyre and gabbro) there are in the Minong range many basic lava flows similar in all respects to those on the St. Croix and Douglas ranges. There are a few flows of porphyritic diabase. The most marked of these has already been mentioned as the rock immediately overlying the fourth conglomerate,[4] and this is, as far as known, the highest and consequently the latest of the lava flows of the Lower Keweenawan in this district. No exposures of quartz-porphyry nor of red syenite were seen on that part of the Minong range west of R. 5 W., although pebbles of these rocks, especially the former, are abundant in some of the conglomerates.

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[1] Page 25.

[2] See page 49.

[3] U. S. Grant: Bull. Geol. Soc. Amer., vol. XI, pp. 503-510, 1900.

[4] Page 48.

Typical Section of the Lower Keweenawan.

Good exposures of the Lower Keweenawan rocks exist in many places. Of especial interest are those in Sec. 13, T. 42 N., R. 11 W., and those along the Totogatic-once in Secs. 5, 6 and 8, T. 43 N., R. 9 W. But by far the finest and most continuous exposures are along Dingle creek in Secs. 12 and 13, T. 43 N., R. 10 W., and Sec. 18, T. 43 N., R. 9 W. Beginning with the lowest flows of the southwest quarter of the last section and going northwest, or stratigraphically upwards, the following belts of rock are found:[1]

I. The highest hill in this quarter section is called Mt. Dingle. It and the exposures just to the north consist of several flows of more or less decayed, reddish, diabase amygdaloids.

II. Four flows of hard, reddish, luster mottled diabase, but not the common variety of luster mottled diabase or melaphyre. The pyroxenes of these flows become one-eighth inch in diameter, or a little larger.

III. One flow of melaphyre quite similar to the last, but a little finer grained and porphyritic with feldspars.

IV. Several flows of reddish amygdaloidal, fine grained melaphyres. These extend to the west line of Sec. 18.

V. One flow of coarse melaphyre. Associated with this flow is some medium grained, hard, fresh, gray diabase.

VI. Several flows of reddish diabase amygdaloid.

VII. One flow of coarse melaphyre, with broken up upper surface. The flow which underlies the second conglomerate.[2]

VIII. The second conglomerate.[3]

IX. One flow; the peculiar melaphyre which overlies the second conglomerate.[4]

X. One flow of coarse melaphyre. This extends into Sec. 12, T. 43 N., R. 10 W., and has a surface width of about a quarter of a mile.

XI. A number of flows of diabase amygdaloids, usually red-

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[1] See geological map, plate XIII.

[2] See page 47.

[3] See page 46.

[4] See page 47.

dish; some of the flows are luster mottled, but the pyroxenes rarely exceed one-eighth inch in diameter. In these flows are the pits of the Weyerhauser location.

Dip and Strike.

In the district shown on the geological map of the Minong range (plate XIII) the strike averages almost exactly northeast and southwest. There are commonly only small variations from this direction due to local irregularities and to the slight bend in the range which is shown west of the center of the map. At the northeastern end of the map the strike becomes more inclined toward the east, reaching about N. 60° E. at the conglomerate exposure in the southwest quarter of Sec. 33, T. 45 N., R. 8 W. Farther east the direction of strike gradually changes until it is nearly east and west, but this change does not take place as far west as has been supposed, for exposures in the vicinity of Drummond, which is about six miles east of the conglomerate exposure mentioned above, still show a strike much removed from east and west. At one of these exposures (southeast quarter of Sec. 32, T. 45 N., R. 7 W.) about half a mile southwest of Drummond the strike is N. 55° E., and at another exposure at the Rock-cut dam on White river (southeast quarter of Sec. 4, T. 44 N., R. 7 W.), the strike is N. 45° E.

The dip of the rocks in the district shown in Plate XIII averages about 26° degrees towards the northwest, being thus a little greater than on the St. Croix range and less than on the Douglas range.[1] In general the dip becomes steeper the farther one goes toward the northeast or east. This is more especially true in the area east of that shown in plate XIII.

Limits of the Lower Keweenawan.

The northern and northwestern limit of the rocks of Lower Keweenawan age is the southern or southeastern limit of the Upper Keweenawan, and the boundary between these two formations is spoken of under the next heading. The southern or

[1]See page 12.

southeastern limit of the Lower Keweenawan was located in one place on the Numakagon river about two miles southeast of Cable. Outcrops of trap occur in the northeast quarter of Sec. 20, T. 43 N., R. 7 W., at 1,808 paces N. and 396 W. on the north side of the river, and at 1,630 paces N. and 405 W. on the south side of the river. Outcrops of the gneiss of the Archean occur at 1,775 paces N. and 22 W.,—a low outcrop at the water's edge,—on the south side of the river, and at 1,668 paces N. and 130 W., also on the south side of the river. To the southwest of this section the boundary between the Lower Keweenawan and the older rocks has not been definitely located. To the northeast and east, however, the boundary has been carefully located most of the distance from Numakagon lake to the Montreal river.[1]

THE UPPER KEWEENAWAN.

No exposures of the Upper Keweenawan rocks have been found within the district studied in detail, i. e., from the west side of T. 42 N., R. 11 W., to the east side of T. 45 N., R. 6 W. Farther east, however, there are exposures of the northward dipping Upper Keweenawan rocks and at least two exposures of those which dip south. The exact limits of the area underlain by rocks of this age are thus unknown, and so the boundary between the two divisions of the Keweenawan on plate XIII is not necessarily accurately located. This boundary line may be farther to the northwest than is shown on this map, and in that case the area underlain by copper-bearing traps would be increased. The uppermost flow of the Lower Keweenawan thus far identified is the porphyritic diabase which immediately overlies the fourth conglomerate[2] and the base of the Upper Keweenawan is supposed to be close to this flow. As on the St. Croix range[3] the boundary between the Lower Keweenawan traps and the Upper Keewenawan conglomerates, sandstones and shales coincides practically with the boundary between the till

[1]See Irving and Van Hise: U. S. Geol. Survey, Mon. XIX, pl. II.

[2]See page 48.

[3]See page 7.

and the pine barrens, the latter being underlain by the Upper Keweenawan.

Two supposed outcrops of Lower Keweenawan trap have been reported to the northwest of the boundary between the two parts of the Keweenawan as delimited on plate XIII. One of these is in the northeast quarter of Sec. 18 (1,765 paces N. and 728 W.), T. 42 N., R. 11 W. The other is near by, but on the north side of the Totogatic river. The first was visited by Messrs. H. M. Adkinson and J. L. Goodvin. The supposed outcrop is about ten feet square and is composed of a fine grained gray gabbro or diabase. The second is reported by Mr. E. Goodvin to be about the same size as the first. It seems very doubtful that these rocks are actually in place; they are more likely to be large boulders mostly covered by the drift.

There have been rumors of exposures of traps in hills just to the northwest of the Eau Claire lakes. Messrs. H. F. Little and J. L. Goodvin spent two days in a careful search for outcrops in these hills and failed to find any rock in place. It is exceedingly doubtful that exposures of traps exist in these hills, which are till hills rising from the sandy barrens.

SPECIAL DESCRIPTIONS.

Serious prospecting for copper on the Minong range has been carried on at different times for a number of years; many of the localities worked have, however, been farther east than the limits of the area investigated during 1900. There are, however, several places within these limits where exploratory pits have been sunk, and at two of these places (the Mudge and the Weyerhauser locations) work has been done in the present year.

Copper occurs on the Minong range in the same manner as on the St. Croix and Douglas ranges, and it has one other manner of occurrence, i. e., in the conglomerates. The associated minerals are the same as on the two other ranges. Prehnite is not abundant, but is found in places, as at the Montrose location.

The Mudge Location.

During the summer of 1900 Mr. D. A. Mudge conducted explorations in Sec. 5, T. 42 N., R. 10 W. Near the center of the northeast quarter of this section some stripping and shallow trenching were done to better expose the rock which here rises in a bare hill west and south of the Totogatic river. The work disclosed (1) some of the usual epidotized masses of rock in which there was some copper, now largely changed to malachite, and (2) a brecciated belt in the trap. This belt is from two to five feet in width and appears to dip and strike with the surrounding rocks, i. e. the dip is toward the northwest. The breccia is cemented by quartz, calcite, and a little prehnite and in this cement are small pieces of copper.

In the southeast quarter of this section at the juncture of the second conglomerate and the overlying melaphyre digging has been done in several places and a test pit has been sunk. Here the lower part of the melaphyre is more or less decayed and in the lowest foot of the melaphyre, at the actual contact and in the upper inch or two of the conglomerate copper is found in the form of irregular nuggets. The largest of these seen by the writer was about two by one and a quarter by one-third inch. A number of them were an inch in length and half an inch in thickness. These nuggets are heavily coated with malachite and in some cases have been entirely changed to malachite. The copper occurs in this quarter section wherever the contact between the conglomerate and the overlying melaphyre has been dug into. In fact copper has been seen in a number of other places at this contact for some distance to the southwest.

A letter from Mr. Mudge, dated Sept. 28, 1900, states that this test pit has reached a depth of 25 to 30 feet; that the copper nuggets continued to be found; and that the conglomerate was carrying copper in very fine particles.

The Weyerhauser Location.

From February to May, 1900, exploratory operations were conducted in the northwest quarter of the southeast quarter of

Sec. 12, T. 43 N., R. 10 W. This work was done under the direction of Mr. E. W. Durant, Jr., and consisted mainly of trenching and the sinking of two pits. The first pit is on the west side of Dingle creek and the second on the east side, where is also a long trench. The first pit is said to be forty feet in depth and the second sixty feet. At the time the writer examined this location each pit was about half full of water, and there was some water in the trench.

The trench, which is a few rods east of the second pit, runs northwest and southeast, thus cutting across the strike of the different beds. Beginning at the southeast the following flows are crossed, the distances across each being horizontal distances:

I. Thirty-eight feet of a reddish amygdaloid diabase.

II. Eighty-two feet of another similar flow, the last 32 feet being amygdaloidal.

III. Sixty-five feet of a similar diabase, the last 25 feet being amygdaloidal. This is the flow in which the second pit (and most probably the first also) is sunk. Thus far the trench has been along level ground, but now the ground slopes abruptly to the north, the slope being steeper than the dip, which is here about 25°. At the foot of the slope the trench is filled with water for a distance of 40 feet. Beyond this is

IV. The next overlying flow, which is a reddish, fine grained melaphyre.

The second pit (i. e., the one on the east side of the creek) starts in near the top of the third flow mentioned above and goes down vertically but does not, as far as the rock thrown out shows, go through this flow. The rock is a rather fine grained diabase which varies from black to dark red in color. Sometimes it is cut by very fine grained dark red veins. There are some pseudamygdules of chlorite and some amygdules which are mainly of quartz. The upper fifteen to twenty feet of this flow is amygdaloidal and more or less fractured. The fractures in places are quite numerous and are filled by quartz and calcite. In this fractured or brecciated part of the rock are some yellow masses rich in epidote (epidotized areas). These are from a few inches to eight feet, or possibly more, in diameter. Copper frequently occurs in the cement in these yellow masses. One of these masses, eighteen inches in diameter, was broken to pieces and the copper collected. The largest copper nugget weighs nearly four ounces; it is over two inches in length. In all approximately a pound of copper was found in this yellow mass. One, at least, of the yellow masses in the pit contains a considerably larger proportion of copper. The native copper is coated somewhat by malachite and there is also some red copper oxide (cuprite).

The pit on the west side of the creek starts in the upper part of this same flow,—or what certainly seems to be the same flow,—and does not seem to go through it. Here the rock is less brecciated, but more amygdaloidal and more epidotized. The copper found here is said to have come mainly from near the bottom of the pit.

At the camp office here are a number of fine specimens of copper ore from these two pits. Among these are some which are nearly pure copper. The largest of these was estimated to weigh about seven pounds, and there are several that would weigh from one to three pounds each.

It is to be regretted that work here was discontinued, for this is a place sufficiently favorable to warrant further exploration.

The Montrose Location.

At this place (northwest quarter of northwest quarter, Sec. 12, T. 44 N., R. 9 W.) work was begun in Nov., 1890, but the explorations have been abandoned for several years. Mr. M. B. Tarr furnished the information concerning the depth of the different pits and the thickness of each bed penetrated by the pits. The accompanying sketch (figure 1) shows the location of the outcrops and of the test pits.

Pit No. 1. This is at the base of an outcrop of porphyritic diabase (VI), the porphyritic crystals of which are of feldspar. The pit is now about five feet deep and has caved in. It was originally ten feet deep and its bottom was in conglomerate (V). Specimens of this conglomerate thrown out from the pit show large numbers of pebbles of reddish quartz-porphyry. A small amount of copper is reported from this conglomerate.

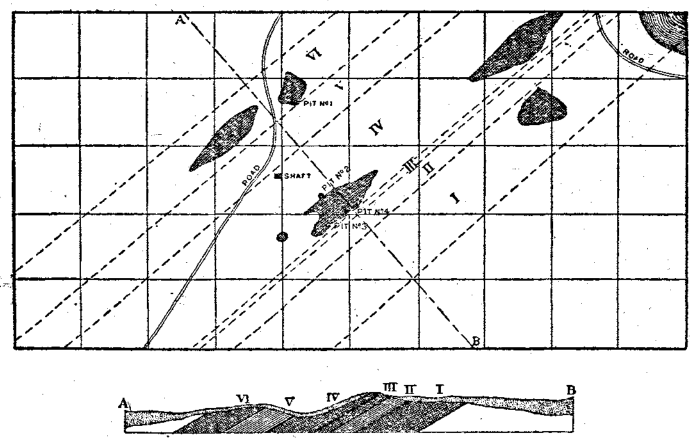

FIG. 1.—MONTROSE LOCATION. Sketch map of N. ½ of N. W. ¼, Sec. 12, T. 44 N., R. 9 W. The cross lines are drawn 100 paces apart. Shaded areas represent outcrops. I, fine grained, reddish, luster-mottled diabase. II, the third conglomerate. III, reddish, more or less brecciated amygdaloid. IV, fine grained, reddish diabase. V, the fourth conglomerate. VI, porphyritic diabase.

The shaft. This is seven by twelve feet and is 87 feet deep, the first 80 feet being in reddish diabase (IV), and the last seven feet being in reddish amygdaloid more or less brecciated (III). The reddish diabase is in part amygdaloidal and at times epidotized. In the epidotized areas there is at times copper both in and without the amygdules. In a few amygdules the copper forms a complete or nearly complete outer ring. The brecciated amygdaloid contains copper in the cement and in the amygdules, but the copper is more abundant when the rock is epidotized. The chief minerals of the cement and the amygdules are calcite, quartz, and prehnite, the copper usually occurring in the last. Other minerals are epidote, chlorite, and laumontite. When the shaft was dug copper is reported to have been very abundant in the brecciated amygdaloid. This belt of rock certainly appears to be one in which copper might occur in considerable amount. Naturally the best specimens have been taken away.

Pit No. 2. This pit is 80 feet in reddish trap (IV), 18 feet in brecciated amygdaloid (III) and 8 feet in conglomerate (II). At the base of the conglomerate was sandstone (finer part of conglomerate), and on this a drift was run 15 feet towards the northwest. The chief pebbles of the conglomerate are of reddish quartz-porphyry. The conglomerate is reported to have carried considerable copper, and some of the conglomerate pieces on the dump now show a little of this metal which has largely changed to malachite. The brecciated amygdaloid carries a little copper, but less than at the shaft.

Pit No. 3. The other pits are vertical. This one runs along the dip, i. e., towards the northwest about 22°. The pit is 10 feet deep and is at the contact of the reddish diabase (IV) and the underlying brecciated amygdaloid (III).

Pit No. 4. This is near the junction of the reddish diabase (IV) and the brecciated amygdaloid (III). It penetrates 6 feet of the latter, 18 feet of conglomerate (II) and 9 feet into the sandstone. No. III is here little brecciated.

Other Locations.

Two pits have been sunk in the northwest quarter of Sec. 2, T. 44 N., R. 6 W. One of these pits (1,645 paces N. and 1,400 W.) is on the east side of Preëmption creek, is perhaps 60 feet deep and was sunk probably 15 years ago The rock thrown out is a dark, fine grained, very much fractured and decayed trap. With this is a smaller amount of reddish amygdaloid, which contains a little chalcopyrite and a soft, metallic, silver white mineral. On west side of the creek is another pit (1,645 paces N. and 1,445 W.). This is shallow and is sunk in a reddish fractured diabase.

In the southeast quarter of Sec. 2 (932 paces N. and 285 W.), T. 43 N., R. 7 W., a pit was sunk during the summer of 1900. This is perhaps 15 feet deep and at the time it was visited was partially filled with water. The rock here is a fine grained, dark gray, rather fresh diabase. In small seams there is some chalcopyrite.

There are a number of other places where copper occurs, and in some of these a very small amount of work has been done,—what could readily be done with a prospector's hammer or pick. One such place is in the southeast quarter of the southwest quarter of Sec. 28 (210 paces N. and 1,310 W.), T. 43 N., R. 10 W., and is known as the Williams location. Copper occurs here in and without the amygdules of a dense black trap. There are some epidotized areas in the rock, but these do not contain as much copper as does the rock outside of these areas. This is an exception to the usual relation of the copper to these epidotized areas. A thickness of three feet of this copper-bearing rock is exposed, and exposures of adjacent rock show that there may be a thickness of about 8 feet of the copper-bearing rock.

CHAPTER V.

THE COPPER DEPOSITS.

In this chapter it is proposed to present a brief discussion concerning (1) the mode of occurrence of the copper, (2) where to search for copper and (3) the value of the copper deposits. This discussion is based on the facts collected in the districts of the state that have been studied in detail, and the statements made and the conclusions arrived at are to be applied only to these districts, although many of the statements will hold equally good for other areas of copper-bearing rocks in the Lake Superior region.

MODE OF OCCURRENCE.

Copper occurs mainly as the native metal. At times this has suffered alteration, especially when at or near the surface, to the green carbonate (malachite) and much less frequently to the blue carbonate (azurite). These two minerals occur only in comparatively small amounts. The red oxide of copper (cuprite) occurs in small quantity at the Weyerhouser location, it is in all probability an alteration product from the original native metal. In many places on the Douglas range and in a few places on the Minong range copper occurs in the form of chalcopyrite (a brass-yellow mineral composed of sulphide of copper and sulphide of iron) and in smaller amounts as chalcocite (a dark, almost black mineral composed of sulphide of copper). In no place in this district have the last two minerals been found in sufficient quantities for mining, nor does it seem probable that deposits of these minerals of economic importance will be discovered. In order to be of value as ores chalcopyrite and chalcocite must occur in greater abundance than is necessary for the native metal. Thus in Wisconsin the deposits of copper which are likely to prove of economic value are those in the native state.

Native copper occurs in this district in four ways: (1) in amygdules, or in pseudamygdules, or in small particles scattered through the rock; (2) in minute seams; (3) in veins; (4) in conglomerates.

The most common mode of occurrence is in amygdules where the copper partially or completely fills the amygdaloidal cavities. The minerals associated with this metal in the amygdules, and imbedded in which the copper frequently occurs are quartz, calcite, prehnite, and epidote. Commonly at least two of these minerals are present in any copper-bearing amygdaloid. At the Montrose location the copper, instead of being imbedded in the other minerals of the amygdules, in some cases surrounds these minerals, thus forming the outermost substance in the amygdules.

An exceedingly abundant accompaniment of the copper is epidote. Very frequently along seams or in areas of indefinite shape the rocks are highly charged with this mineral. Commonly these epidotized masses are of roughly spherical form and vary in diameter from an inch to several feet. With the epidote in such masses is much quartz, especially in the amygdules. The copper occurs in the amygdules and also scattered throughout the rock. Many of the occurrences of copper on the St. Croix range are in epidotized parts of the rock, and the same is true on the Douglas range, especially at the Percival location where the richest parts of the rock are those highly charged with epidote. These epidotized masses of rock, also carrying copper, are known on the Minong range.

Prehnite is comparatively rare on the St. Croix range, but is known from at least two places. One of these is on the Moose river in Sec. 2, T. 44 N., R. 13 W., where this mineral occupies the amygdules in common with the copper.[1] The other locality is on Crotty brook near the center of Sec. 30 (1,120 paces N. and 995 W.), in the same township. On the Douglas range, however, prehnite is a common accompaniment of the copper, as for instance at the Copper Creek and the Percival locations,

[1] See page 28.

where this mineral is abundant in the copper-bearing rock. On the Minong range prehnite is not abundant, but is known from a few places. One of these is the Montrose location.

In minute seams in rock, which is otherwise copper-bearing, there are at times films or thin sheets of copper. These are usually found in places where the rock is highly charged with epidote. Some of these thin sheets of copper have been found in the Admiral Dewey lode at the Fond du Lac location.

The veins thus far discovered are most frequently parallel to the layers of rock. These veins occur most commonly in the upper amygdaloidal parts of the flows, and frequently along the veins there has been a brecciation of the adjoining rock. Where this brecciation has not taken place the veins are narrow, commonly only an inch or so in width, but where the adjoining rock is brecciated the vein minerals have cemented the rock fragments and the total thickness of the vein material may be increased to a few feet. The minerals of these veins are chiefly quartz, calcite and prehnite. Copper occurs in small irregular pieces scattered through the vein material. One peculiar occurrence of copper in these veins is at the Copper Creek location where this metal is in wire-like forms penetrating either calcite or quartz. In one vein these wire-like pieces of copper appear to be covered by a thin coating of native silver. At the Montrose location the brecciated amygdaloid has a vein whose thickness is increased due to the fracturing of the adjoining rock, and at the Weyerhauser location the same feature is present. Here, however, the copper occurs at times in nuggets of considerable size in the fractures and at the intersections of several of the fractures. But the most of these nuggets occur in fractures which are included in certain highly epidotized areas of the rock. Nuggets are also found in these fractures in the Little Maude vein at the Fond du Lac location.

A few small veins have been found which cut the rocks at a marked angle to the different layers, as at the Percival location. These contain the same minerals as the other veins already mentioned and also carry copper.

Mention should also be made of two kinds of vein-like forms which sometimes occur in the copper-bearing rocks. The first are found in the upper parts of certain lava flows and consist of very fine grained flinty rock, which is red to yellow in color. This exists in vein-like forms an inch or more in width and sometimes carries copper, as on Crotty brook in Sec. 7, T. 43 N., R. 13 W., on the St. Croix range, and at the Chippewa (North Wisconsin) location on the Douglas range. The second kind of vein-like form occurs at the Aminicon location. Here a fracture is filled with material, which has probably fallen into a crack in the top of a lava flow, and this material was later cemented by certain minerals. In this vein are chalcopyrite and chalcocite; native copper has also been reported.

The vein-like form at the Stewart shaft at the Fond du Lac location is not a vein, but an intruded layer of igneous rock which has been epidotized and impregnated with copper.

Conglomerates interbedded with the traps have not been found on the St. Croix and Douglas ranges, but they are known on the Minong range.[1] Where these carry copper this metal occurs in the cement of the rock, and not, as far as seen, in the pebbles. Quite commonly the copper is in part altered to malachite. The pieces of copper vary in size from minute grains to small nuggets. Commonly more copper is found in a conglomerate at or near its contact with the adjacent rocks. The contact deposits at the Mudge location occur mainly in the amygdules or pseudamygdules or other cavities in the somewhat decayed lower part of the melaphyre flow, and in smaller amount in the conglomerate itself.

WHERE TO SEARCH FOR COPPER.

In prospecting for copper operations should be confined to the area underlain by the igneous rocks or the interstratified sediments of the Lower Keweenawan. (See geological maps, plates I, VII, VIII, IX, XII and XIII.) There is little probability of finding copper in any considerable amount either in the sandstone of the Upper Keweenawan or in the Lake Superior sandstone, unless possibly at the contact of these sandstones with

[1] See pages 46-49.

the underlying traps. In the northern belt of Lower Keweenawan rocks (i. e., on the St. Croix and Douglas ranges) the search should be confined within a few miles of either the southern or the northern boundary of the traps,—not because there is no copper in the intervening district, but because outcrops are so scarce that the chances of discovering a copper-bearing layer are very much less. In the southern belt of the Lower Keweenawan rocks (i. e., on the Minong range) the most numerous outcrops occur within a few miles of the northern boundary of the traps, and consequently this is the best locality for prospecting. At the same time other places removed from this north boundary are suitable places for prospecting provided outcrops are not too scarce.

The hills and the streams should be visited, for in these two places outcrops are more likely to occur. An outcrop of some peculiar kind of rock may sometimes be located by tracing fragments of this rock, which have been distributed by a stream or by glacial agencies, back to their original source. In doing this it must be borne in mind that the general glacial movement in this district was from north to south, but the latest movement on the St. Croix and Douglas ranges was towards west of south, and on the Minong range towards east of south.

It is not necessary here to go into a discussion of the origin of the copper deposits. It is only needful to state that the copper, while it probably was originally disseminated in very minute particles throughout the igneous rocks, has been deposited in its present position by circulating waters. Those areas in which the water was most free to circulate, other things being equal, would be areas in which the most copper was deposited. Thus it is evident that the deposits of this mineral are to be searched for in those parts of the rock which were actually loosely textured or which were crossed by fractures. And such loosely textured portions of the rock are the amygdaloidal upper parts of the lava flows or the interstratified conglomerates. When these, especially the amygdaloids, were also fractured, they became still better places for the deposition of copper. Particularly porous amygdaloids, i. e., those containing large and abundant amygdules, have been explored at several places, notable among which are the Fond du Lac, Chippewa (North Wisconsin) and Percival locations; and fractured amygdaloids have been also explored, notably at the Fond du Lac, Weyerhauser and Montrose locations.

The copper deposits of the district under discussion most commonly occur in these upper amygdaloidal parts of the lava flows. The criteria by which a separation can be made between two flows, and consequently the upper part of one flow located, have already been given.[1] When such an amygdaloid part of a flow has been located, careful search should be made for copper both in the amygdules and in any veins or fractured parts of the rock. At times at the surface the native copper is not discernible, and its presence may be detected by the green and blue alteration products or stains, malachite and azurite. Areas where the rock is highly charged with epidote, i. e., areas of a yellow or yellowish-green color, should be searched for particularly, as in these copper is likely to occur.

When the upper amygdaloidal part of a flow has been located, the following conditions may be of service in determining whether it should be prospected farther than can be done by a careful examination of the surface and of those parts which can be broken off with a hammer or pick: (1) The actual presence of native copper, or of the alteration products. (2) The loose texture of the rock, i. e., the presence of large amygdules near together or of very numerous small ones. (3) A layer of such amygdaloid which is several feet in thickness. (4) The presence of fractures or veins in the rock, in which are the usual vein materials. (5) The presence of areas which are highly charged with epidote. There is very little chance of success in further prospecting in an amygdaloidal layer unless at least one, and preferably several, of these conditions are fulfilled.

And to the above may be added that, other things being equal, such an amygdaloidal layer which immediately underlies, or im-

[1] See pp. 12–15.

mediately overlies, a thick non-amygdaloidal layer of rock, or which lies between two such thick layers, furnishes a more promising place to prospect than an amygdaloid not thus located. Such a thick non-amygdaloidal layer is formed by the main mass of a melaphyre flow, the upper part of the flow being commonly amygdaloidal. The distribution of these thick melaphyre flows is shown on the St. Croix range (plate VII) and on the Minong range (plate XIII). It is hoped that the location of these flows, as given in the maps, will be of aid in conducting future explorations.

Careful search for conglomerates should be made, and when one is found it should be examined in regard to its copper content. It seems that, in the district under discussion, the copper is more likely to be concentrated near the contact of the conglomerate with the adjoining rocks than in the middle of the conglomerate itself. The extent of the conglomerates thus far known is indicated in part on plate XIII. They extend, in all probability, further northeast and southwest than the map indicates, and there may be other conglomerates which future exploration will bring to light. For instance, the third conglomerate would not be known at all were it not for the pits at the Montrose location.

In the description of the fault along the line of junction of the Keweenawan traps and the Lake Superior sandstone[1] attention was called to the marked brecciation of the traps for a considerable distance from the contact. Such a brecciated zone would form an excellent channel for circulating waters to pass through and might consequently be regarded as a very favorable location for copper deposits. As far as known, however, this brecciated zone has not furnished much promise in this line, and there is reason to think that it does not contain richer deposits of copper than can be found elsewhere. A possible explanation of this is that the most of the copper was deposited in its present position in the traps prior to the date of this fault and that since the faulting there has been little copper deposition. A similar fault exist between the traps and the Lake

[1] See pp. 17–20.

Superior sandstone on the eastern side of Keweenaw point, and along this fault no important copper deposits have been found.

The junction between the Upper Keweenawan and the traps of the Lower Keweenawan is a possible zone for the concentration of copper. No copper has as yet been reported from this contact in the district under discussion, but it has not been explored carefully.

Large veins have not been discovered in the traps in this district, but if such can be found they will furnish promising locations for exploration.

During the Glacial period nearly all the decayed or weathered rock was removed from the traps of the Keweenawan, leaving them fresh and sound except for such changes as had gone on at a considerable distance below the surface. Post-Glacial weathering commonly extends only a slight distance from the surface, often only the fraction of an inch, and only in a few places, such as in some fissured and very porous rocks, do the effects of weathering reach a few feet, or in exceptional cases a number of feet, below the rock surface. The deposits of copper were in very large part, if not entirely, formed long ago and since their formation very many feet of rock have been removed by erosion in this district, so that what is now exposed at the surface was once deeply buried. With these two facts in mind,—i. e., the slight amount of weathered rock and the presence at the surface today of rock which was once deeply buried,—it becomes clear (1) that there is just as much likelihood of deposits of copper being found at or near the rock surface as at a distance of many feet below the surface, and (2) that such deposits are quite as likely to be rich at or near the surface as many feet farther down.

The practical application of these principles will lead to exploration in two stages. The first stage is shallow exploration through the drift; the second stage is rock work.

The first stage of exploration should be shallow because it is much less expensive than rock work. Stripping, accompanied by shallow trenches or test pits in the rock, will bring to view a much larger area of a given copper-bearing bed than the same amount of energy and money expended in sinking a deep test pit or a shaft. Where the drift material overlying the bed rock is so thick as to make stripping very expensive or impossible, recourse must be had to a shaft or deep test pit, but even here the copper-bearing rocks can be explored more easily by running drifts and cross cuts from the bottom of a shallow shaft than by sinking a deep shaft.

The advantage of surface or shallow explorations is spoken of here because there is an opinion, prevalent among those who are engaged in exploratory work for copper in Douglas county, that rich copper ore is not to be expected at the surface, that any copper-bearing layer will grow richer with depth, and that a given layer is not satisfactorily proved to be worthless until it has been followed to a depth of at least 200 or 300 feet from the surface. There is absolutely no known reason why the copper deposits in Douglas county should increase, or decrease, in richness with depth. A given amount of a copper-bearing bed explored in a horizontal direction is just as reliable an index of the contents of the bed as the same amount of exploration in a vertical direction, and the former is usually by far the cheaper method of exploration. In fact if, as is reported, the copper deposits in Michigan are elongated more in a vertical (i. e. in the direction of dip) than in a horizontal direction, the ore at times occurring in ore-chutes, a given amount of horizontal exploration is worth more than the same amount of vertical exploration.

During a visit to the copper district of Keweenaw point the writer made it a particular point to inquire concerning this idea of a deposit's increasing in richness with depth. The question was put to mine superintendents, mining engineers, and mining captains, and the invariable answer from these men, whose practical work and long experience rendered their statements reliable, was that this idea had no basis in fact; a given deposit might grow richer, or it might grow poorer, with depth; there was no rule.

Special attention is called to the advantage of surface or shallow explorations, because when any piece of property is being explored that kind of exploration which will yield the most results with the least expense should be undertaken first.

It is not intended, however, to state that the second stage of exploration involving rock work should be undertaken under no circumstances. When by shallow exploration on a certain piece of property a bed of some richness or an ore-chute of some promise on a bed has been located this may warrant rock work. If a careful investigation, with fair sampling and analyses, shows at the surface a local area of sufficient promise, this warrants rock work. A locally rich area or ore-chute may extend in a vertical or inclined direction as deep or deeper than its surface extent. To test this dimension of an ore-body it is necessary to put shafts into the rock. Such shafts ought commonly to be sunk not in a vertical direction but along the dip of the lava flows. Commonly it is advisable to locate the shafts at the tops of the flows, using the bottoms of the next overlying flows as the hanging walls of the shafts. If an ore-chute has a pitch it may be that the shaft following the dip will pass from the rich belt, in which case it will be necessary to run drifts at various depths across the ore-chute. However, it cannot be too strongly emphasized that to warrant rock work of this kind a sufficiently promising area should be located below the drift by surface exploration.

In summary we may say as to method of exploration that since there is so much copper-bearing rock which can be explored on or near the surface, the first stage should consist in thorough shallow exploration in order to find the most favorable places at the rock surface. If these most favorable places prove to be sufficiently promising, the second stage of exploration, deep rock work, is warranted.

VALUE OF THE COPPER DEPOSITS.

As has already been stated, and as the foregoing description of the geology of Douglas county and of the Minong range[1] has confirmed, the Keweenawan traps and conglomerates of this

[1] See chapters I and IV.

district are the same in nature, in origin and in age as the copper-bearing rocks of Keweenaw point, and consequently might contain similar deposits of copper. In regard to the identity of the rocks of the two districts it may be well to quote certain statements made by Prof. R. D. Irving:[1]

It is therefore proper that I should insist here that this identification [of the bedded diabases and amygdaloids of the St. Croix Valley with those of Keweenaw Point] is also indisputable; and that it is so because of the absolute identity in nature and structure of the rocks of the two regions, and because the Keweenaw belts have been followed continuously from the eastern end of Keweenaw Point to the Saint Croix River.

In support of the first of these assertions, I have to advance the following facts. The predominant fine-grained basic rocks of the two regions are so completely the same in mineral composition, even to the alternation-products, that thin sections of rocks from the two districts placed side by side are not distinguishable from one another. The only approach to an exception to this statement is the somewhat greater prominence of prehnite as an alteration-product on Keweenaw Point than on the Saint Croix. The rocks of the two regions present precisely the same amygdaloidal, pseudamygdaloidal, and compact phases. The amygdules are made of the same minerals in both, associated in the same ways. Native copper occurs in the Saint Croix Valley in the same manner, and with the same associates as on Keweenaw Point. Here and there an exposure may represent a dike so far as can be perceived, but almost everywhere the Saint Croix Valley rocks present precisely the same bedded structure as seen in those of Keweenaw Point. This is displayed, not only in the common step-like contours of the exposures, but the individual beds may be readily separated from one another, each bed often showing sharply marked its upper vesicular and lower compact portions. Moreover, where the dip is high and the exposures are large, as on the Snake and Kettle rivers of Minnesota, there is to be seen a continuous series of beds, in all many hundred feet thick and in every respect similar to the alternations which obtain on Keweenaw Point. The same interstratified poryhyry-conglomerates and sandstones are met with in both regions, and in both regions carry at times native copper. Interbedded original felsitic porphyries also occur in both regions.

In support of the second assertion, as to the actual continuity of the Keweenaw Point and St. Croix rocks, I have to say, in the first place,

[1] "The Copper-bearing Rocks of Lake Superior;" U. S. Geol. Survey, Monograph V, pp. 239–241, 1883.

that the evidence of this continuity is precisely the same for the distance between the Montreal and the Saint Croix, as for that between the Montreal and Keweenaw Point, or even the distance between the eastern part of Keweenaw Point and its western portion at Portage Lake; that the continuity has never been disputed for the two latter distances; and that it should therefore be accepted at once for the first named distance. The evidence for all the distance between Keweenaw Point and the St. Croix is just as strong as that ever appealed to to prove the continuity of geological formations anywhere, save in those very rare and exceptional regions where the rocks are completely bare. This evidence consists in the frequent recurrence, at short intervals, of the same kinds of rocks, with the same structure and stratigraphical arrangement; and such evidence is forthcoming in the present case. From Keweenaw Point to the Saint Croix, the formation has been traced mile by mile with a constant recurrence of precisely the same bedded basic rocks, with the same amygdaloidal and compact portions to the beds, of the same associated felsitic porphyries, of the same interstratified porphyry-conglomerates, and of the same native copper in veins, altered amygdaloids and conglomerates. The same division of the series into a Lower or prevailingly eruptive member, and an Upper or detrital member, is also everywhere present. From Keweenaw Point to the region of Long Lake, some even of the subordinate members are recognizable as continuous. For the particulars of this evidence, I refer to the detailed description of Foster and Whitney's report, of Vol. III of the Geology of Wisconsin, and of the present work; to the United States Land Office township plats; and to the collections of the Wisconsin Geological Survey, and of the survey made for this report. If this evidence does not constitute proof of continuity, then no geological formation in the United States has ever been proved to be continuous for more than a very few miles—rarely for more than a mile—except in the plateau region of the western territories.

In regard to the copper deposits of Wisconsin Prof. Irving made the followings statements:[1]

Without the boundaries of the state of Michigan, the attempts at copper mining have been but feeble, and utterly inadequate to prove or disprove the existence of workable copper deposits. In Wisconsin native copper has been met with all along the course of the southern Keweenawan belt from Montreal river to the Saint Croix. Running from the Montreal, in Sec. 2, T. 47, R. 1 E., southwest and west, is a

[1] Ibid., pp. 428–429. Both the quotation which precedes and that which follows were written nearly twenty years ago.

belt of distinctly bedded and often amygdaloidal diabases in which copper has been seen in greater or smaller quantity both in crossing veins and in altered diabase belts, at the crossing of each stream, the intervening areas being drift covered. At the crossing of Montreal and Bad rivers this belt is worthy of further examination.[1] Beyond Bad River, to the southwestward, float copper is exceedingly common, and traces of it are here and there met with in the ledges themselves. Unfortunately the country is one covered with heavy drift accumulations, through which only the harder and more enduring, and therefore non-cupriferous, beds ordinarily project. The indications are that, but for the overlying sheet of drift, this region would be as productive in copper as that of Keweenaw Point.

Rounding the turn at the western end of the great Keweenawan syncline, in the Saint Croix Valley, we find the drift covering lighter, and here, in the vicinity of Snake and Kettle Rivers, and thence northeastward into Douglas county, in Wisconsin, are found plainly bedded diabases and amygdaloids carrying copper with interbedded cupriferous conglomerates. The region is one which in the early day of mining excitement on Lake Superior was so remote and inaccessible, that the flood of copper hunters which at that time spread west from Keweenaw Point failed to reach it. It still lies almost wholly unexplored, while promising more to the copper hunter than any other portion of the entire extent of the formation outside of the State of Michigan.

Further north and east from the district last described lies the Copper Range of Douglas County, Wisconsin.[2] This range has already been fully described on a previous page as to its position and structural characters. Copper has been found along its course in a number of places, chiefly in epidotic altered amygdaloids, and the general structural characters are such as to indicate the possibility of the occurrence of copper in quantity along this belt. Some little mining has been done at several points, but not enough to lead to any satisfactory conclusions.

Other members of the former Geological Survey of Wisconsin,—Prof. T. C. Chamberlin, State Geologist, and Messrs. E. T. Sweet and Moses Strong,—all agree with Prof. Irving in regard to the identity of the traps of northern Wisconsin with those of Keweenaw point, and consequently they all agree as to the possibility of these traps of northern Wisconsin carrying valuable deposits of copper. In fact the actual identity of the

[1] See Vol. III, Geol. of Wis., pp. 205, 206.

[2] See chapter VI, p. 250 [Copper-Bearing Rocks]. See also Geol. of Wis., Vol. III, pp. 357, 362.

rocks of these two districts is today regarded by all students of the geology of the Lake Superior region as established beyond a doubt.

With this fact established, and the actual presence of deposits of copper in these rocks also established, there remain only two important points to be determined concerning the value of the copper deposits under discussion. These points are the *richness* and the *extent* of the deposits.

The results of several analyses of copper-bearing rock from the St. Croix and the Douglas ranges are given below, the first two being from the former and the others from the latter range:[1]

I. An average three pound piece of rock from the highly epidotized area on the Moose river in Sec. 14 (675 paces N. and 925 W.), T. 44 N., R. 13 W., described on page 27. Speciment No. 8,054.	0.51 per cent.
II. Average of samples from the Moose river in Sec. 2 (765 paces N. and 870 W.), T. 44 N., R. 13 W., described on page 28. Specimen No. 8,072.....	0.67 per cent.
III. Average of samples of the small part of a flow exposed in the bottom of a test pit at the Culligan location in Sec. 31 (1,697 paces N. and 113 W.), T. 47 N., R. 14 W., described on page 33. Specimen No. 8,497.	4.19 per cent.
IV. Average samples from the ore thrown out from a pit or trench at the Copper Creek location in Sec. 15 (233 paces N. and 41 W.), T. 47 N., R. 14 W,. described on page 4. Specimen No. 8,401..	0.29 per cent.
V. Average samples from the brecciated belt at the Copper Creek location, described on page 35. Specimen No. 8,417[2]	0.35 per cent.
VI. Selected samples from pit on hill top at the Copper Creek location, Sec. 15 (480 paces N. and 500 W.), T. 47 N., R. 14 W., described on page 36. Specimen No. 8,425[3]..........................	1.60 per cent.

[1]These analyses, except X and XII, were made by Prof. W. W. Daniells of the University of Wisconsin. XII was made by Mr. George H. Ellis of Chicago and X by Mr. E. F. Burchard of Northwestern University.

[2]The copper here appears to be coated by a film of silver, but a test for silver gave a negative result.

[3]Also tested for nickel, but with a negative result.

VII.	Selected four pound piece from the "vein" at the Stewart shaft on the Fond du Lac location, described on page 37. Specimen No. 8,764. See next analysis	3.64 per cent.
VIII.	Same as last. In taking from No. 8,864 the forty grams for examination two pieces of metallic coper were found weighing 1.34 grams. To ascertain if this was an average sample another portion of forty grams was taken which gave..	0.39 per cent.
IX.	Average samples from a fractured vein-like area in the Little Maude lode, Fond du Lac location, described on page 38. Specimen No. 8,326	0.99 per cent.
X.	Other samples same as last....................	1.25 per cent.
XI.	Average six pound piece from one of the highly epidotized areas in the shaft at the Percival location, described on page 42. Specimen No. 8,706.	1.37 per cent.
XII.	Same as last, one pound piece.................	1.21 per cent.

In regard to the richness of the deposits the foregoing analyses show that there are certain bodies of rock which contain sufficient copper to be termed copper ore. Ore which averages one per cent. of copper will, with the present prices, under favorable conditions and economic working produce a profit. And rock which contains less than one per cent. of copper may, under very favorable conditions, be sometimes worked at a profit. But such ore must occur in beds or veins several feet in thickness and of considerable extent vertically or horizontally, i. e., large amounts of the ore must be accessible. Moreover, it takes a large amount of exploration, and even some actual mining and stamping of the ore, and the consequent expenditure of a considerable amount of money, to show that any given deposit can most probably be worked at a profit.

It should be borne in mind, however, that these analyses, while being in some cases analyses of the average of small masses of the rock, are in no cases average analyses of a bed or vein which has been shown to have this average copper content for any considerable extent. And just here is the last and the important, point to be established concerning the value of these copper deposits,—are any of them extensive enough to be worked at a profit? This is a question, not of theory, but of fact, and a perfectly conclusive answer to it can be had only as a result of extensive exploration. At the same time some light may be thrown upon it by a consideration of the results of the exploration already done and by a consideration of certain geological features.

As far as the results of the exploration which has been carried on thus far were open to the inspection of the Survey,[1] it can be stated that in no place was a deposit of copper, which was of sufficient richness, shown to be of any great extent. The results of some of the old explorations were not available, nor was it possible to investigate certain workings now filled with water, but the Survey parties were very freely allowed to investigate the workings in active operation. In several places a layer of sufficiently good ore one or two feet in thickness was exposed, but, where exploration had been sufficient to disclose this layer for some distance along the strike or dip, the layer was found to have either too small a copper content for its thickness or to decrease in copper content along the dip or strike. In layers, in which were highly epidotized masses containing copper in considerable amount, it was found, where full investigation could be made, that these masses were of limited extent and that outside of them there was only a small amount of copper. On the other hand there were some places where a small amount of a copper-bearing layer was exposed, and what was exposed was of a good quality of ore. In these cases nothing positive can be said about the extent of the good ore until further work has been done.

One noticeable fact in the Lake Superior copper-bearing district is the irregular and uncertain distribution of the copper in almost any given place. A certain amygdaloid, or conglomerate, or a vein, or an ore-chute, which is highly charged with copper, very frequently shows marked variations of its copper content within even a few feet, and within a short distance it may lose entirely its copper-bearing character. This "bunchy"

[1]The explorations carried on on the Douglas range in the spring, summer and fall of 1900 have not been examined by the Survey.

nature of the deposits is a characteristic of the Keweenaw Point district, where even the best copper-bearing layers are in places very poor in copper, and where in even the richest mines much barren rock is encountered in the ore-bearing layers. Because of this sporadic distribution of rich rock in a given copper-bearing layer, it is clear that an investigation of such a layer at one point will show nothing conclusive as to the average richness of the layer. If paying deposits of copper are found in northern Wisconsin, it is therefore to be expected that the copper will, in general, be irregular and bunchy in its distribution, precisely as on Keweenaw point. This matter of the irregular and bunchy distribution of the copper is emphasized because it presents a real difficulty in judging as to whether or not a copper deposit is sufficiently valuable to warrant thorough exploration and, if it be sufficiently rich to warrant working, further difficulty in its exploitation. However, if ore-chutes are found as rich as in the mines of Michigan, which have been successfully operated, these difficulties should not prevent development.

In a number of places it is noticeable that the flows of trap are of small thickness and that several of these flows are copper-bearing. Thus in a given thickness of rock there are several amygdaloidal layers, in each of which copper is deposited in small amounts. It seems reasonable to state that, if in this same thickness of rock there had been but one amygdaloidal layer, this would have served as a place of concentration for the copper which is now scattered in several layers. This was in view when the statement was made that, other things being equal, an amygdaloidal layer between two thick non-amygdaloidal layers was a promising place to search for copper.[1]

The absence of interbedded conglomerates in the traps of the St. Croix and Douglas ranges may have no bearing on the question of the value of the copper deposits. Moreover, it is not impossible that such conglomerates actually exist on these ranges and that future explorations will bring them to light.

[1] See p. 67.

The frequently reported finding of "float" copper masses in the drift should be noted, but these loose pieces may have been transported by glacial ice from localities many miles distant. However, should a considerable number of these pieces be found at one locality, this fact would indicate the nearness of a ledge from which these pieces were derived. In such a case careful search should be made for this ledge, bearing in mind the fact that there is frequently a creep of rocks down a hillside, and also bearing in mind the direction in which the copper masses may have been transported by streams or by glacial agencies. The parties of the Survey have not found any drift nuggets of copper.

CONCLUSIONS.

In addition to the description of the strictly geological features, a report by a state geological survey on the economic geology of any district should discuss, in a calm and unprejudiced manner, the conditions which are favorable and those which are not so favorable to the district under consideration. These conditions should be discussed in order that those interested may know what the prospects of success are, that they may weigh these prospects, and therefore govern their explorations and expenditures in the light of this knowledge. The position of a state survey in a report of this nature is exactly that of an individual who has been intrusted to make a report on a given property. He would be untrue to his trust should he fail to state the facts which were favorable to the property under investigation, and he would be just as untrue should he present only the favorable side of the case and leave untouched the side which might not be so favorable. It is, however, always much more pleasant and much more agreeable (a survey or an individual who makes a favorable report is very likely to be held in high esteem by those for whom the report is made) for a survey or an individual to make an extremely favorable report, than it is to make an unprejudiced report which presents both sides of the case, but at the same time the duty which a survey owes to its state, or an individual to his employers, cannot be overlooked.

In this report an attempt has been made to cover this ground, as far as was possible in the present state of the investigation. A final report which the Survey contemplates issuing when the copper-bearing rocks shall have been studied in detail throughout the state, will, on account of greater accumulations of data, be able to discuss this subject more exhaustively.

The first edition of this report has been interpreted by some to state that no copper-deposits of economic value will ever be found in the district under consideration. This is clearly not correct; no such statement was made,—nor is any such statement made in this edition of the report,—and such an interpretation does not seem to be justifiable. Under the conditions it would have been folly to have made definite statements as to what the future would, or would not, bring forth.

The facts concerning the copper-deposits in the district under consideration may be summarized as follows: (1) The identity of the rocks with those of Keweenaw Point. (2) The presence of native copper. (3) The presence, in places, of sufficient copper to form an ore of value. (4) In some of these places exploration has shown that the rich rock is only of limited extent. (5) In some places exploration has not gone far enough to show the extent of the rich rock. (6) The "bunchy" distribution of the copper in any layer. (7) The presence in a given thickness of rock of several amygdaloidal layers, rather than one layer. (8) The finding of "float" copper.

From a consideration of these facts one point is very clear, and that is the possibility of copper deposits of economic value being found. Another point is equally clear, and that is that to the present time no such deposit has been proved to exist. In regard to another point,—i. e., whether or not such deposits will be found,—it is impossible with our present knowledge to give a definite answer.

In the discussion of the copper deposits it should be clear that the facts brought out by explorations apply most completely to the actual properties on which the explorations have been made. These facts apply less completely to adjacent properties and to the district in general, although even here they have some force. Most of the explorations have been on the Douglas range. There are still, however, considerable parts of this range which have not been explored. Practically no exploration has been done on the St. Croix range, and a comparatively small amount has been done on the Minong range, at least within the district here reported on. The St. Croix and Minong (at least in its western part) ranges differ from the Douglas range in one important particular, and that is in the presence of numbers of thick flows of melaphyre, as shown on plates VII and XIII. The importance of these melaphyre flows has already been spoken of.[1] And the Minong range differs from both the others in the presence of conglomerates interbedded with the traps.[2]

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[1] See pp. 67, 77.

[2] One hastily reading this report might think that there is a contradiction between the quoted statements of Prof. Irving (pp. 71–73) and the conclusions of Prof. Grant (pp. 78–80) concerning the existence of copper in economic quantities in Wisconsin. However a close examination of the two will show that there is no contradiction in fact. Prof. Irving wrote his report not long after the discovery of important deposits of copper at Calumet and Houghton. This naturally made him hopeful that these discoveries would be paralleled by other important discoveries of paying deposits of copper at various other places in the Lake Superior region. However he nowhere says that such deposits will be discovered. Twenty years have gone by since Prof. Irving's report was written, and notwithstanding extensive exploration in various parts of the Lake Superior region, including Isle Royale, no other district than that of Keweenaw point has become an important producer of copper. Cautioned by these facts, Prof. Grant has confined himself to an impartial statement of the facts he has ascertained and of the principles upon which the expenditure of money for exploration is warranted, without venturing to express an opinion as to whether or not in the future copper deposits of economic value will be discovered in Wisconsin.

C. R. VanHise.

APPENDIX.

The descriptions of the St. Croix and Douglas ranges stand in this edition of this report precisely as they were in the first edition, except for the note at the bottom of page 55 of the first edition, which note is incorporated in this appendix. Since these descriptions were written some additional exploratory work has been done, statements concerning which are given below.[1]

RECENT WORK ON THE ST. CROIX RANGE.

During the fall of 1899 Mr. E. A. Arnold, accompanied by Mr. C. E. Bailey and some miners, made an examination of a portion of this range. Blasting was done at four different places,—two on Moose river and two on Crotty brook. It is reported that the results of this examination were very favorable and that the rock obtained by blasting was rich in copper.

RECENT WORK ON THE DOUGLAS RANGE.

Comparatively little work has been done on this range since the summer of 1899, except at the following locations: Black River Falls, Fond du Lac, North Wisconsin (or Chippewa). The writer visited the Culligan, Upper Black River Falls, Black River Falls, Copper Creek and Fond du Lac locations in March, 1900, in company with Messrs. E. A. Arnold, John Bardon and S. N. Dickinson. Unless a location is mentioned below, it is to be understood that at such a place no work was done during 1900.

[1] For information concerning the work done on the St. Croix range in the fall of 1899 and on the Douglas range in 1900 the Survey is indebted to Mr. Kirby Thomas, of West Superior, and Mr. James Bardon, of Superior.

Culligan location.—In March, 1900, comparatively little work had been done in addition to that already described. In 1900 surface work was continued and a "vein," having a width of 20 to 30 feet, and in places of 45 feet, is said to have been traced across two forty-acre tracts.

Upper Black River Falls location.—A small amount of work was done here (S. E. 1/4 of Sec. 28, T. 47 N., R. 14 W.) in two amygdaloidal layers, one above the falls and one just at the foot of the falls. Since March, 1900, some additional work has been done at this place.

Black River Falls location.—Two tunnels were dug at this place (S. E. 1/4 of Sec. 21, T. 47 N., R. 14 W.). The tunnels are below the falls and in the bottom of the river gorge. One of these runs about parallel with the contact of the trap and the sandstone, but in the trap. The other cuts across the trap flows about at right angles to the strike. In March, 1900, the first tunnel was about 30 feet in length and the second about 75 feet. No work was done here in the summer of 1900.

Copper Creek location.—In March, 1900, it was found that very little work had been done here since this place was examined in the summer of 1899, and little was done in the summer of 1900.

Fond du Lac location.—A shaft, about 50 feet deep, was sunk on the Little Maude vein after the Survey's examination of this location in 1899. This was visited in March, 1900. The shaft shows that the fractured portion of this flow continues to carry copper in the direction of the dip in about the same amount as was found in the trenching near the surface. Very little work was done here in the summer of 1900.

Aminicon Falls location.—At this place (S. E. 1/4 of Sec. 29, T. 48 N., R. 12 W.) some small veins of quartz, which occur in the traps a short distance south of the standstone contact, were explored. Specimens brought from this place show chalcocite and galena and assays are reported to show copper, silver and lead.

North Wisconsin (or Chippewa) location.—At this place work has progressed to a marked degree. The shaft has been sunk to a depth of 200 feet and from the bottom of the shaft cross-cuts have been run north and south. In November, 1900, the north cross-cut was 300 feet long and the south one 250 feet in length. These cross-cuts intersect quite a number of amygdaloidal flows, and along some of these flows drifting has been done. In all there are 250 feet of drifts.