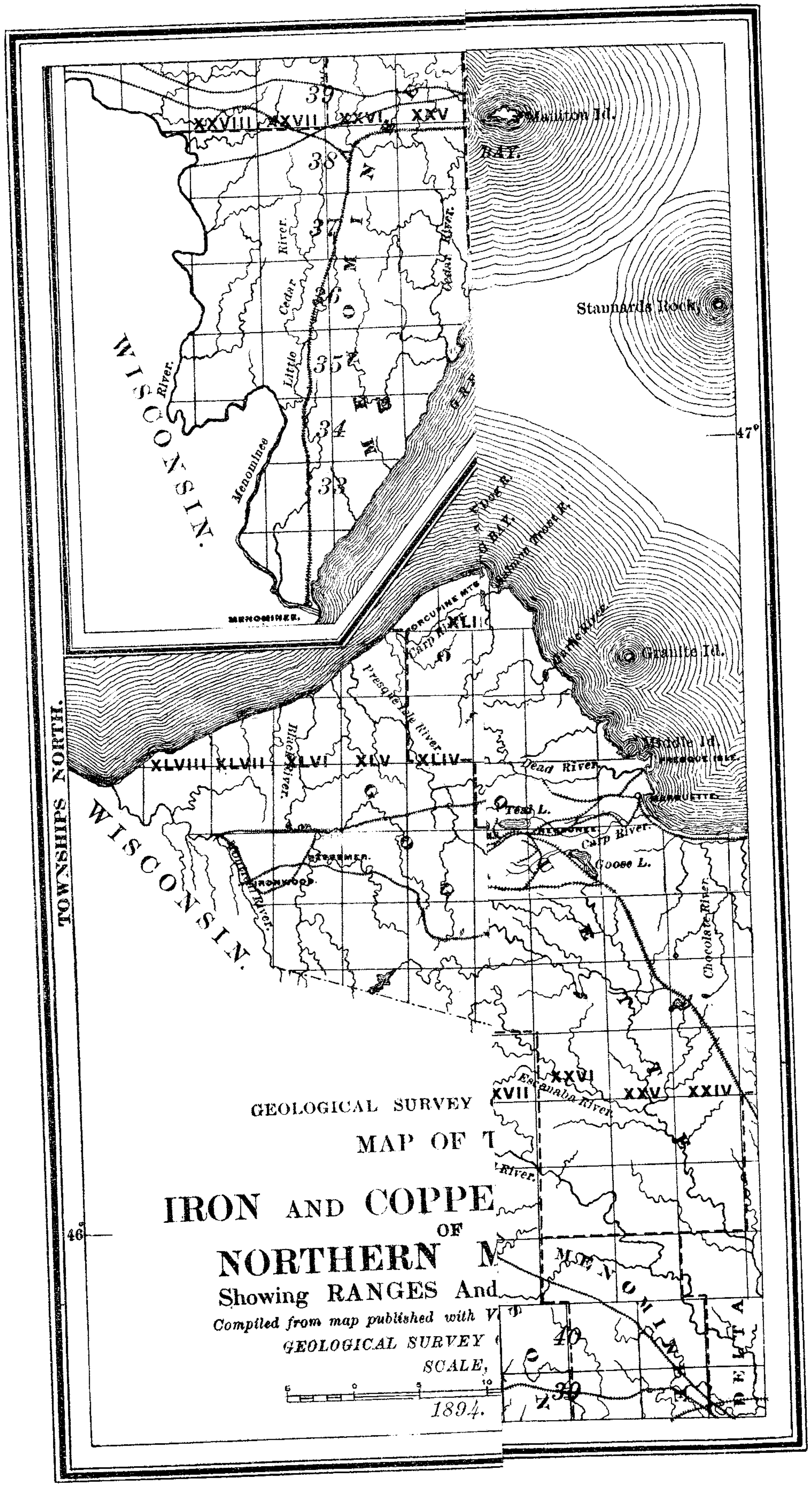
GEOLOGICAL SURVEY OF

MICHIGAN

1881-1893.



GEOLOGICAL SURVEY OF MICHIGAN

LUCIUS L. HUBBARD, STATE GEOLOGIST

UPPER PENINSULA

1881-1884

LOWER PENINSULA

1885-1893

VOL. V

PART I. UPPER PENINSULA; IRON AND COPPER REGIONS

PART II. LOWER PENINSULA; DEEP BORINGS

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MICHIGAN

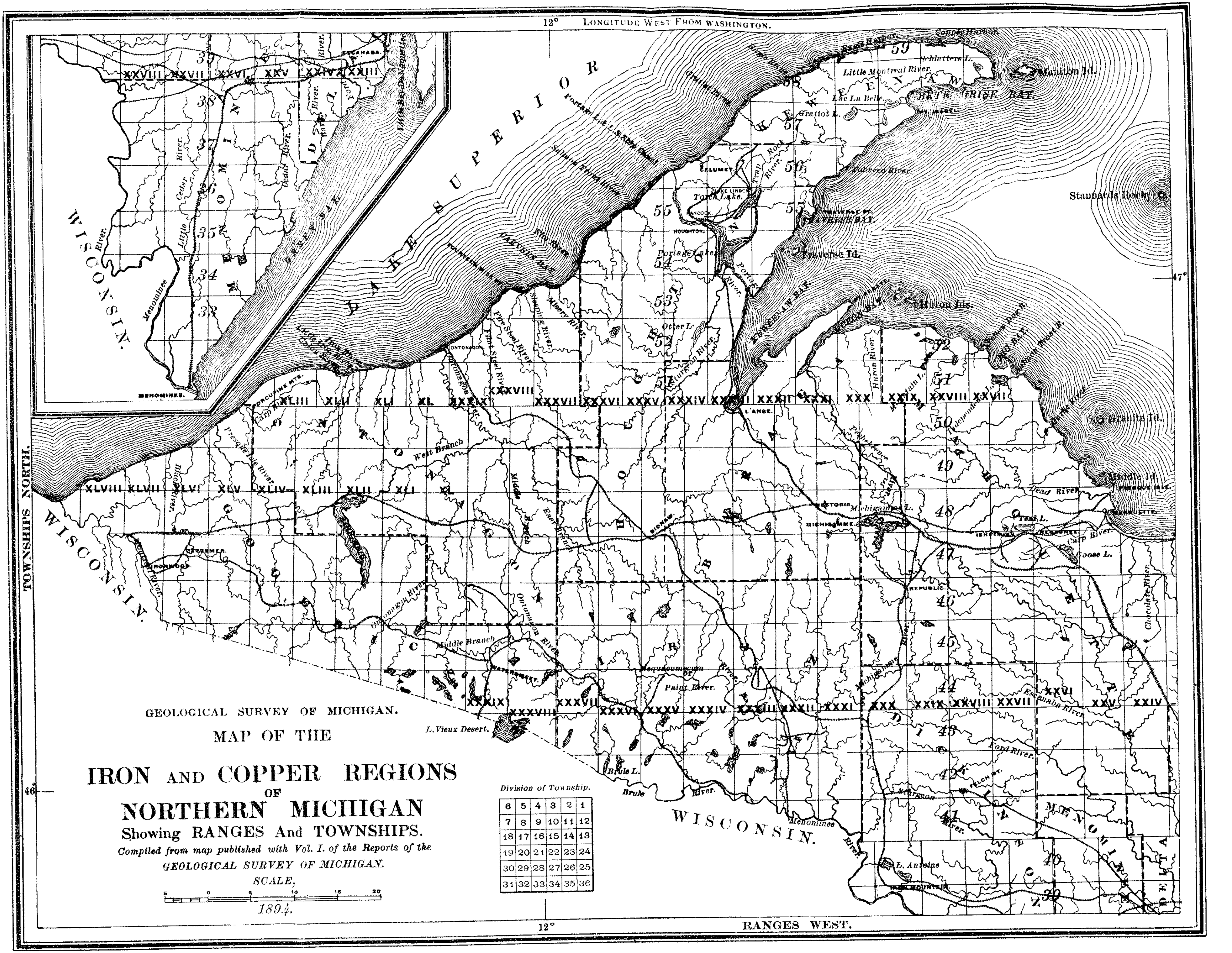
UNDER THE DIRECTION OF

THE BOARD OF GEOLOGICAL SURVEY

LANSING

ROBERT SMITH & CO., STATE PRINTERS AND BINDERS

1895


GEOLOGICAL SURVEY OF MICHIGAN.
MAP OF THE
IRON AND COPPER REGIONS
OF
NORTHERN MICHIGAN
Showing RANGES And TOWNSHIPS.
Compiled from map published with Vol. I. of the Reports of the
GEOLOGICAL SURVEY OF MICHIGAN.
SCALE,
1894.
Division of Township.
6 5 4 3 2 1
7 8 9 10 11 12
18 17 16 15 14 13
19 20 21 22 23 24
30 29 28 27 26 25
31 32 33 34 35 36
12°
LONGITUDE WEST FROM WASHINGTON.
RANGES WEST.
TOWNSHIPS NORTH.
46°
47°
LAKE SUPERIOR
WISCONSIN.
WISCONSIN.
WISCONSIN.
GREEN BAY
KEWEENAW
HOUGHTON
ONTONAGON
GOGEBIC
MARQUETTE
DICKINSON
MENOMINEE
DELTA
Copper Harbor
Eagle Harbor
Manitou Id.
Little Montreal River.
Lac La Belle
Gratiot L.
Torch Lake.
CALUMET
HANCOCK
HOUGHTON
Portage Lake
Traverse Id.
KEWEENAW BAY.
Huron Ids.
HURON BAY.
Huron River.
Stannards Rock.
Granite Id.
Middle Id.
MARQUETTE.
Dead River
Carp River.
Goose L.
Teal L.
REPUBLIC.
Michigamme L.
MICHIGAMME.
L'ANSE.
ONTONAGON
PORCUPINE MTS.
Presque Isle River.
Black River.
West Branch
Middle Branch
Ontonagon River.
East Branch
BESSEMER.
IRONWOOD.
L. Vieux Desert.
Brule L.
Brule River.
Paint River.
Michigamme River.
Escanaba River.
Ford River.
Sturgeon River.
Chocolate River.
Menominee River.
L. Antoine
Fire Steel River.
Flint Steel River.
Sturgeon River.
Otter L.
Misery River.
Little Iron River.
Iron River.
Cedar River.
Little Cedar River.
Menominee
MENOMINEE.
ESCANABA.
Little Bay de Noquette
XLVIII XLVII XLVI XLV XLIV XLIII XLII XLI
XLIII XLII XLI XL XXXIX XXXVIII XXXVII XXXVI XXXV XXXIV XXXIII XXXII XXXI XXX XXIX XXVIII XXVII
XXXIX XXXVIII XXXVII XXXVI XXXV XXXIV XXXIII XXXII XXXI XXX XXIX XXVIII XXVII XXVI XXV XXIV
XXVIII XXVII XXVI XXV XXIV XXIII
59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39
39 38 37 36 35 34 33

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PREFATORY HISTORICAL NOTE.

The last published report of the Michigan Geological Survey, in the series of which the following pages constitute Volume V, was written by Dr. Carl Rominger, at that time State Geologist, and was published in 1882. It described work done and observations made by Dr. Rominger in the iron region of the upper peninsula, west and south of Marquette.

The first part of the present volume, also written by Dr. Rominger, beside covering work done in the iron region in 1881 and 1882, also includes observations made in the copper region in the following year or years. The manuscript of this report was in the possession of the Board of Geological Survey at the time when Dr. Rominger's successor, the late Charles E. Wright, was appointed State Geologist, in May, 1885.*

Accompanying this report is a small map of the western part of the upper peninsula, copied from a map published with Vol. I of the series. Although defective in several minor details, which could not well be corrected without making an entirely new map, from independent data, it will serve the purpose for which it is intended, to help the reader orient himself in connection with the descriptions in the text.

The second part of the present volume is a paper by Dr. A. C. Lane, on deep borings in the lower peninsula, and is based on work done by the late Mr. Wright. As stated in my letter of transmittal, this paper was practically completed during the

*Referring to the first part of this report, Dr. Rominger, in 1883, said: "The description of all the results obtained comprises the space of about fifty or sixty printed pages, too small for a separate publication in book form. I respectfully suggest, therefore, to wait with it until the results of another year's work can be added and a volume can be printed corresponding with the previous four volumes." The long delay in the publication of said report has, doubtless, been caused by the feeling which gave rise to Dr. Rominger's request—that the complete report by itself was not large enough to fill a volume. The smallest of the preceding volumes of the same series was of 262 pages, while the largest was of 581 pages.

See Dr. Rominger's report for 1882-83, in report of the State Board of Geological Survey, 1893.

administration of my immediate predecessor, Dr. M. E. Wadsworth, and in its original form was sent to the Board of Geological Survey in 1892. It has since been revised and somewhat enlarged, and is preceded by a brief chapter on the origin of salt, gypsum, and petroleum. The printing of this volume was begun in November, 1893. The reproduction of the plates that accompany it, although begun a month earlier, was not completed until November, 1894.

Charles E. Wright was State Geologist from May, 1885, to the time of his death, in March, 1888. In May of the latter year Dr. Wadsworth succeeded Mr. Wright, and continued to hold the office until May, 1893. During Dr. Wadsworth's administration the Survey had its headquarters in the Mining School building, at Houghton, where its corps had the exclusive use of a room, and unrestricted access to all departments of the school. Up to that time, except possibly during the terms of Dr. Alexander Winchell, the Survey had no habitation other than the private offices or houses of the respective State Geologists. To this want of permanent quarters is doubtless due the fact, that, in times past the collections of the Survey and much of its property have been dispersed or lost.

In the absence of a suite of rock samples that illustrate the geological formations of the State, many of them its economic products, each incoming State Geologist must collect anew, and, in the absence of records and field notes, must inform himself by personal inspection in the field, or through his assistants, what are the relations of the rocks and their geological significance. In a territory like that of northern Michigan, vast, in many places difficult of access, and of a complex geological structure, the acquisition of this knowledge must and does take a number of years, especially when we consider the shortness of the field season, and the limited means applicable to the work. In view of these facts, it should not be a matter of surprise that the resignation of one State Geologist and the death of another have retarded the fruition of labors, which, at least during the administrations of Rominger and Wright, were largely personal.

Of rock samples collected by the Survey previously to Mr. Wright's time, none appear to have been handed down to Mr. Wright. Mr. Wright, in three seasons of field work, during which he spent probably more than half the season between May and November in the field, gathered some 3,300 specimens of rocks, which, together with others contributed by the Hon. John M. Longyear and other parties representing large land interests in the upper peninsula, formed the nucleus of our present collection. Notes of surveys made by these parties were also placed at the disposal of the Survey and copied into its records; a number of maps and sketches were, in whole or in part, completed by Mr. Wright, to illustrate respectively the topography of the country and its geological phenomena, and descriptions of about two hundred thin sections, made from rocks in the collection, were written by him. In the lower peninsula Mr. Wright visited salt wells, and by the aid of the information gathered there, prepared some sixty sections of deep borings, which appear at the end of this volume. Inasmuch as the office work of the Survey, as above intimated, was largely done by Mr. Wright, without the aid of the corps of assistants that did much of the field work, his term of office was undoubtedly occupied in zealous labor for the State, to equip himself thoroughly for the responsible task of writing up its geology; but, unfortunately for his successors, he left nothing that was available for immediate publication, and many of the facts observed and conclusions reached by him, after years of research and study, died with him, and were thus lost to the public.

During the administration of Dr. Wadsworth the collection was augmented to 7,000 or more specimens, and from many of them thin sections were made, and examined, and written descriptions of several thousands of these were prepared. These descriptions, together with the field work and work on the maps and sketches, that had been going on since Dr. Wadsworth's appointment, leave in the possession of the Survey a large amount of material that, with the necessary acquaintance on the part of the State Geologist with the geological structure of the country, and with sufficient means to push the work rapidly forward, would place the latter official in a position to publish the results of the Survey's investigations with less delay than has heretofore been the case. Some of the results of this work have already been given to the public in Dr. Wadsworth's annual reports to the Board of Geological Survey, and in his "Sketch of the Iron, Copper and Gold Regions," all of which were published by the Board in its report of 1892. The last named sketch was to be revised and enlarged by Dr. Wadsworth and Mr. A. E. Seaman, and made a part of this volume, but those gentlemen have been unable to complete and furnish the promised manuscript.

The Geological Survey now has a building of its own, in Houghton, partly equipped with the apparatus most necessary to its work. This work, details of which appear from time to time in the annual reports of the State Geologist, may be expected to proceed henceforth under favorable conditions, and will, it is hoped, prove of service to the economic interests of the State.

LUCIUS L. HUBBARD,
State Geologist.

GEOLOGICAL SURVEY,
Houghton, November, 1894.

PART I.

GEOLOGICAL REPORT

ON THE

UPPER PENINSULA

OF MICHIGAN

EXHIBITING THE PROGRESS OF WORK FROM 1881 TO 1884

IRON AND COPPER REGIONS

BY

C. ROMINGER

ACCOMPANIED BY A MAP AND TWO GEOLOGICAL CROSS-SECTIONS

TABLE OF CONTENTS.

B

LIST OF PLATES.

PART I.

ERRATA.

PART I.

Page 6, 18th line, for "portion" read "portions."
" 6, 5th line from bottom, for "Huronion" read "Huronian."
" 10, 5th line from bottom, for "granates" read "granites."
Pages 10, 53 and 54, "Gogogashung" is otherwise spelled "Gogogashugun."
Page 28, 7th line, for "othoclase" read "orthoclase."
" 44, 10th line from bottom, for "comglomerate" read "conglomerate."
" 26, 23d line, for "McGillis's" read "Gillis's."
" 68, 17th line from bottom, for "heiter" read "either."
Pages 87 and 120, 14th and 6th lines, respectively, from bottom, for "escarpements" read "escarpments."
Page 105, 5th line, for "amygaloid" read "amygdaloid."
Pages 134, 136, 137, and 142, for "Montreal River" read "Little Montreal River," to distinguish it from the stream on the boundary between Michigan and Wisconsin.

CHAPTER I.

INTRODUCTION.

THE present report, describing the results of a continued examination of the geological structure of the Lake Superior district, forms a supplement to the previous, fourth volume of reports in which the same district has been the object of description as far as it was then investigated. Meanwhile a much larger area came under observation, which partly was formed of the same rock complex as the one described in the former volume, of the so called Huronian system, partly represented a more recent group of rocks known as the Copper-bearing or Keweenaw group, because it encloses immense deposits of metallic copper and as Keweenaw peninsula is altogether formed of this series of strata.

To communicate the newly acquired information about the Huronian rock series, I thought it best to reconsider the different chapters of the former report and to add to them in each place the concerned facts accumulated by the more recent investigations.

The description of the copper-bearing series is appended in a separate chapter.

I continue to use the name "Huronian" for the entire rock complex of Lake Superior called by Foster and Whitney "Azoic," "Archaean" by Dana, and by the Canadian geologists and their followers "Eozoic," sub-divided in two groups, an older called *Laurentian* and a younger, *Huronian*.

I stated in the previous report that in the Marquette region, where I commenced my investigations, no tenable line of demarcation between an older Laurentian, and a younger Huronian group unconformably deposited on the first, could be observed.

The Laurentian gneissoid and granitic rocks, according to the theory of the Canadian and other geologists, are highly altered former sedimentary rocks. The occurrence of supposed foraminiferous animal remains in limestone belts interstratified with these gneisses was considered as an infallible proof for the correctness of their theory, but recent unbiased investigation of these supposed animal remains, named Eozoön, has evinced to full satisfaction their inorganic concretionary nature.

The lower granitic and-gneissoid portion of the rock group in the Marquette region exhibits the characters of an eruptive and not of an altered sedimentary rock.

The asserted nonconformity between a Laurentian and Huronian division is not observable in that portion of country; even the Canadian geologists dissent on the conformity or nonconformity question and in special instances their opinions, which part of an exposed series of rock beds belonged to the Laurentian and which to the Huronian, widely differ.

This state of confusion was recently censured in a critical review of the literature concerning these older rocks, published by Messrs. Whitney and Wadsworth, in order to vindicate the right of priority for the name "Azoic" rocks instead of "Archaean" or "Eozoic" (Laurentian and Huronian).

The name "Azoic," no doubt, is prior to the others, but at the time it was first used the absence of organic remains in these rocks was just as little proved as the later claimed abundance of them for the same class of rocks then called Eozoic.

The criticisms are intentionally one-sided to suit their purpose.

After their representation of the great confusion of opinions existing with regard to these rocks, one might justly expect a proposal of their own, how to transform this chaos into a harmonious system, but instead of an earnest effort to do this, the book abruptly closes with a sneering proposition.

CHAPTER II.

GRANITIC GROUP.

In the previous report, which commences with a description of the geological structure of the environs of Marquette, I have stated the occurrence of large areas of granite some distance north and south of the city, and the intermediate space from four to five miles in width as being occupied by a large body of massive and schistose dioritic rocks, succeeded upwards by argillitic, chloritic and hydromicaceous schistose layers enclosing lenticular seams of hematitic iron ore, which on their part are overlain by a large quartzite formation and by still higher beds of siliceous limestone interstratified with argillitic or hydromicaceous schists of various color, some of them intensely impregnated with hematitic iron oxide.

All these strata I described as being steeply upheaved in a constant axial direction from east to west and as excessively folded and corrugated, suggesting as the principal cause of these disturbances the uprising of the granite into a synclinal trough, compressing the incumbent sedimentary layers.

I further stated that particularly the lower dioritic portion of the rock beds enclosed within this trough was found intermingled with beds of granite, partly parallel to the stratification, partly transversal to it, from which circumstance I inferred the intrusive nature of these belts and suggested that this intrusion occurred contemporaneously with the upheaval of the granite into a trough, and that part of it at least must have been then in liquid or plastic condition.

Generally, a solid crust of granite probably served as a substratum on which the Huronian sediments were laid down, but not often is occasion offered to see the rocks in contiguity well enough exposed to allow a discrimination whether such contact is an original primary one or resulted from subsequent dislocation.

The existence of granite as surface rock at the time the Huronian sediments formed is proved by the occurrence of belts of granite-conglomerates and -breccias in different horizons of the series.

A large belt of conglomerate, formed of rounded, water-worn granite pebbles and schistose rock fragments, cemented by a matrix of similar schistose material, is seen in contact with a granite belt in the S. ½ of Sec. 2, T. 48, R. 26, but this instance is not a satisfactory example of the deposition of sediments enclosing debris of the underlying rock, as the granite pebbles in the conglomerate are totally different from the underlying granite, which is a porphyritic kind largely composed of a cryptocrystalline felsitic groundmass, enclosing quartz grains and orthoclase crystals of larger size. This peculiar variety of granite is typical for the smaller intrusive belts, and most likely the granite in this case came in contact with the conglomerate belt by intrusion.

Better proof for the deposition of Huronian sediments on a base of granite is furnished by another locality in the S. E. ¼ of Sec. 22, T. 47, R. 26, where several knobs, centrally composed of massive granite, are surrounded by a mantle of coarse granite breccia with a well laminated quartzose material as a cement, which breccia is conformably succeeded by a series of steel-gray colored shining hydromicaceous slate rocks, interlaminated with heavy belts of light colored compact quartzite. Granite-conglomerates are also found interlaminated with dioritic schists remote from granite outcrops. Such a belt is, for instance, observable in the N. ½ of Sec. 29, T. 48, R. 25.

The upheaval of the granite and its intrusion into the overlying strata occurred in all probability near the termination of the Huronian period, as we find the granite in contact with any of the Huronian strata up to the youngest, and these always in a dislocated position.

Intrusive belts of granite are usually not found to intersect beds higher than the iron-bearing group, excepting the country north of the Penokee Range in Wisconsin, and also the vicinity of Duluth, in Minnesota, where granite or granite-like rock seams cut across eruptive belts of gabbro, which themselves are more recent than any of the sedimentary strata reckoned to belong to the Huronian group. These granites differ also some

from the ordinary granites at the base of the Huronian and most likely are younger.

The dislocation of the Huronian beds is not exclusively due to the upheaval and intrusion of the granite, as numerous other intrusive rock belts, dioritic or diabasic, intersect the granite as well as the incumbent beds. The dioritic kind of these rocks is the older, as we see it invariably intersected by the diabasic dykes if they come in contact.

The dioritic belts intersecting the granite are lithologically identical with similar rock belts interstratified with the schists of the Huronian group conformably, or also transversely intersecting them; they represent, therefore, one and the same volcanic injection.

As from the massive form of diorites a gradation exists into a schistose condition, and as schistose structure formerly appeared to me a positive proof of a former sedimentary origin, I resorted, in the previous report, in order to explain the similarity in the composition of these schists with the massive diorites, to the hypothesis of a secondary fusion of the lower beds of sediments nearest the focus of central heat and a subsequent injection of the fused part into the folds and fissures of the remainder of the strata. Simultaneously also I supposed the molten mass to have been forced into the fissures and crevices of the adjoining granite. I have since lost much of faith in this suggestion, as I convinced myself that schistose structure is not necessarily the result of aqueous sedimentation, but that cooling eruptive masses under circumstances can assume a schistose form. Not to be confounded with the above mentioned diorites, common to the granitic portion and the incumbent schistose group, are other belts of hornblende rocks, which are found in association with the granite only, and not above it.

While the first have generally a dull, lighter or darker greenish color and massive appearance, the latter exhibit usually great lustre. Their color is blackish or speckled black and white, and most of them are distinctly laminated, running on one side into hornblende-schists, on the other into a gneiss. The blackish hornblende in them is scaly, often hard to distinguish macroscopically from black biotite, and is arranged in interrupted linear layers alternating with the granular feldspathic and quartzose constituents of the rock. Belts of such rock are seen in repeated alternation interlaminated with granite belts; at other times both intersect each other in a network of seams; the gneissoid portions often are plicated in zig-zag lines or into serpentine curves; usually biotite enters into the composition and partially replaces the hornblende.

Different again are the syenitic rocks associated with the granite in certain locations. They are coarsely crystalline, consisting of dark blackish hornblende and of orthoclase without quartz. They form separate hillocks scattered over granite areas.

The doleritic or diabasic rock masses, which intersect in dyke form all the Huronian rocks from the granite to the uppermost beds, played an important part of the disturbing elements acting on the Huronian rock series. As above stated, their eruption occurred later than that of the diorite dykes. The color of these dykes is generally black, if they are fine-grained; gray or black and white speckled, if their crystalline structure is coarse. Often in larger dykes the exterior portion near the enclosing walls are almost aphanitic with conchoidal fracture, while the central portions of the dykes are formed of a magma of larger crystals.

Thin sections examined under the microscope show the components of the rocks to be translucid crystals of plagioclase, transparent augite with pale brownish color, and variable quantities of magnetite. In some of these rocks, if not in all, olivine is an additional component.

A striking similarity exists between these dyke masses and the diabase belts, particularly the so called greenstones of the Copper Range; the resemblance in some instances is so perfect that hand specimens or thin sections of the two compared kinds of rock could not be distinguished if no label were attached to them. Furthermore, such dykes not only intersect the strata of all horizons in the Huronian series, but we observe the identical dykes also cutting across the gabbro belts near Duluth, which form the basal part of the Copper-bearing series. Considering these circumstances, I think to be justified to believe that these dykes intersecting the Huronion group, and the overflow of diabase making part of the Copper-bearing formation, originate from the same source and, although not strictly contemporaneous, form a chain of successive volcanic outbursts actually representing one and the same event in the geological history.

During the progress of the survey I re-examined the vicinity of Marquette and found granite dykes to be much more abundant than I previously knew; particularly on Lighthouse Point I noticed the schistose beds to be intersected by a network of narrow granite dykes which had escaped my attention on former visits to the place.

All these dyke masses have not the typical granite structure but are porphyritic, formed of a fine-grained cryptocrystalline felsitic groundmass in which dimly defined larger orthoclase crystals and grains of quartz are dispersed; generally also linear streaks of biotite and chlorite scales are intermingled and a more or less distinctly laminated fluidal structure of the rock is always observable.

Some of the belts cleave into even flags from one-half an inch to two inches in thickness, which by another vertical cleavage are divided into rhomboidal segments the surface of which is generally covered with a thin coating of silvery shining hydromica. Such a belt is well exposed on the north side of the Lighthouse tower, which I had noticed before, but mistook for a sedimentary layer on account of its laminated structure.

On the north limits of the city and two miles west of it, where the granite dykes are much larger, a gradation from the porphyritic structure to the completely finished crystalline form of ordinary granite is readily observable. I generally observed that the smaller belts of eruptive granite have this porphyritic quality. The granite seams intersecting the dioritic rock series south of Upper Quinnesec Falls, on Menominee River, are of the same nature as those near Marquette; the porphyries of Pemenee Falls are perfectly analogous; but in the latter locality it is not only a narrow band but a succession of porphyritic beds of immense thickness. On the other hand also narrow dykes of granite occur which have the completely crystalline structure of a normal granite. One such instance, which has additional interest by the circumstance that the granite dyke cuts across the iron-bearing rock series, which is rare, can be observed in the Felch Mountain region. In the bluffs south of the Metropolitan mine, formed of heavy quartzite beds richly impregnated with particles of specular iron ore, this granite dyke, fifteen or sixteen feet in diameter, cuts in geniculated course through the quartzrock. The rock underlying the quartzites which dip under high angle northward is a gneissoid hornblende-schist, whose intersection by the granite dyke is not visible on account of large accumulations of talus on its slope.

In the vicinity, T. 42, R. 28, Sec. 33, S. W. ¼, another wedgelike intrusion of granite into the iron-bearing rock series is exposed. The concerned rocks form a low ridge trending east and west. On the south side, separated by a swampy depression, high granite bluffs are in close proximity; on all other sides the ridge is surrounded by a swampy bottom. The north side of this ridge presents near its base low bluffs of a dark green gneissoid hornblende rock, succeeded above by a broad belt of a banded hydromicaceous and quartzose rock which by impregnation with a large proportion of specular ore granules has a steel-gray color with bright metallic lustre; some narrower seams are composed almost purely of iron ore. The strata are nearly vertical, but those on the northern edge of the belt dip southward while on the south part of the belt a dip to the north is plainly observable. Beneath this ferruginous belt we find farther south a large succession of dark greenish, smooth-bedded, minutely scaly biotitic hornblende-schists dipping north. Descending in the succession, the mica-leaves and hornblende-scales of the schists become much coarser and copiously intermingled with brown garnet crystals. This portion of the rock is also much corrugated. Next to it projects a lenticular mass of granite associated with gneissoid seams. The granite mass is parallel to the trend of the formation, but lateral branches of the main mass intersect the strata transversely. Crossing this wedge of granite, we find on its south side the garnetiferous mica-schists continued, dipping north like those on the other side farther on; the smooth-bedded, fine-grained biotitic hornblende-schists appear again, seeming to underlie the garnetiferous beds conformably, and conformably below these the metallic, shining, ferruginous strata repeat, leaning in steeply erected position on the base of the southern granite bluffs. We have here evidently before us a series of strata plicated into a synclinal and another anticlinal fold, the latter ruptured by an intruding granite mass, which rock is there the general surface rock and comes on the south end of the exposure in contact with the uppermost ferruginous strata of the overtilted anticlinal fold.

The granites bordering the south side of the Gogebic Iron

Range and of its continuation into Wisconsin, the Penokee Range came under my observation during the progress of the survey. I found them in every respect analogous to the granites of the Marquette country.

The rocks of that part are not so excessively corrugated; the upheaval lifted the strata more in continuous sheets, and belts of granite intrusive in the incumbent strata could not often be observed, although several granite seams cutting across dioritic schists occurred to me about four or five miles west from the shore of Lake Gogebic.

Following the range, the granite is not always found in contact with the same kind of strata; locally heavy quartzite strata are in contiguity with it. The lower layers of them are often represented by a conglomerate filled with rounded granite pebbles or also by brecciated quartzose beds crowded with orthoclase crystals and cemented by a wax-colored hydromicaceous interstitial mass, which rocks resemble granite so much that it is difficult to distinguish the contiguous beds. These rocks correspond accurately with the rocks I have described in the previous report as occurring on the contact line between the granite and quartzite formation in the north part of T. 47, R. 25 (see pages 15 and 16), which I then supposed to be quartzite altered by its contact with the granite into a granite-like rock; now I am more inclined to consider the rock as a recemented mixture of granite fragments mingled with the arenaceous material which formed the overlying quartzite beds; still it is very singular that the orthoclase crystals copiously imbedded in the mass have all sharp outlines and look as fresh as if they had formed where they are and could not be the debris of a disintegrated granite.

At the above mentioned locality in the N. W. ¼ of N. E. ¼ of Sec. 24, T. 47, R. 43, this singular rock in contact with the granite contains locally an abundance of brownspar which on exposed faces of the rock weathers out, leaving behind ochreous matter which fills the spaces formerly occupied by the spar. Crevices in the rock mass are replenished with galena; explorers have therefore worked considerably in such places and made better denudations than nature would have offered to an itinerant geologist. Only a short distance from the above described locality, in the adjoining Sec. 23, the granite is seen in contiguity with dioritic schists of a brecciated character which enclose large angular blocks of massive diorite of various quality. The granite comes there also in contact with massive diorite belts and intersects them in dyke form. From here westward I followed a trail which frequently leads over dioritic rocks, but never comes far enough south to reach the granite.

In T. 47, R. 46, Sec. 13, the granite is found in close proximity to cherty banded ferruginous beds enclosing seams of good iron ore; below these iron-bearing beds are light colored kaolinitic strata which are in direct contact with the granite. Further west, in Sec. 15 of the same town, the granite comes very close to the ore-bearing quartzite formation in which extensive exploring pits are opened, but I had no opportunity to observe in this place which sort of rock came in contiguity with the granite. The explorers informed me that diorite formed the footwall of the quartzites in which the ore deposits are found, and the diorite joined on the south side the granite. Onward to the west the explorers made to me the same statements, always speaking of dioritic rocks intervening between the granite outcrops and their exploring pits.

Near the Montreal River in the N. W. ¼ of Sec. 27, T. 47, R. 47, I found granite in immediate contiguity with the ore-bearing quartzite and banded jaspery beds.

In Wisconsin, above the island in Gogogashung River, a belt of schistose dioritic rocks intervenes between the granite and the large succession of light colored slaty rocks which form the island. Above these slate rocks are quartzite strata partly brecciated and interwoven with seams of limonitic iron ore. From here to Penokee Gap I did not make any observations regarding the contact line of the granite with other rocks, but at the Gap in the bed of the river, under a railroad bridge, the direct superposition of crystalline limestones (enclosing tremolite fibres) on the granite could be seen. Above the limestone succeeded some beds of quartzite and then a large series of light colored silico-argillaceous schists, which most likely are identical with those composing the island in Gogogashung River. The granates found on Bad River, north of the Gap, I have previously mentioned, and suggested their age to be younger than that of the granite at the Gap, which opinion agrees with the views of the geologists of Wisconsin.

CHAPTER III.

DIORITIC GROUP.

The extension of the survey over a much larger territory than had been examined at the time the previous report was published did not necessitate any essential alteration of my former views concerning this group, but it furnished ample corroborating proof for the correctness of formerly made statements. Local and regional differences of analogous rocks in different remote places were observed, but this is generally to be anticipated in the examination of any rock formation.

The occurrence of lithologically identical belts of diorite in association with the rock series called the dioritic and with the granitic group, and the frequency of intrusive granite belts in the first mentioned group, make it difficult to draw a line of demarcation between the two; their genetic history is too closely allied. I repeat, therefore, what I stated in my first report: "The subdivisions I proposed for the Huronian group were arbitrary, simply made for convenience in the description of related facts." In recent publications of microscopical lithologists who examined rock specimens of the Lake Superior region, without ever having been near it, I see the opinion advanced that the majority of rocks formerly considered to be diorites are in reality diabases, or originated from diabases by paramorphosis.

As I had described the rocks to be mostly genuine diorites, relying on a macroscopical examination, I was particularly interested to ascertain by the microscopical method of studying rocks, whether I was right, or whether these deductions from a comparatively small number of hand specimens really told the truth. During the progress of my work I therefore took particular attention to examine rocks of this class wherever I met with exposures, with regard to the conditions under which they occurred, and to collect as many of them as possible as hand specimens for future microscopical examination. These examinations, although only accomplished with the smaller portion of the collections, are sufficient to convince me of the correctness of my former statements, namely, that the crystalline rocks which form the principal bulk of the Huronian rocks, comprised by me under the name "dioritic group," and all the older intrusive rock belts intersecting the granite subdivision are genuine diorites, composed of hornblende and plagioclase. Uralitic diorites, in which the hornblende is supposed to be an alteration product of augite, are not missing, but comparatively they are rare and represent, as far as spacial extension of the rock masses is considered, only an inconsiderable part of the totality. Furthermore, I observed in several instances where such uralitic rock belts occurred, an intersection of the ordinary diorite by them, which, if this should be found to be the case generally, would prove their more recent eruption and probably their intimate relationship with the doleritic or diabasic dykes mentioned in the previous chapter, which dykes, although in some portions of Lake Superior region quite abundant, contribute as a surface rock comparatively only little to the augmentation of the dioritic mountain masses. These augitic rocks were also never confounded by me with the diorite. The massive crystalline rock belts which compose the great bulk of the so called dioritic group in association with schistose rocks formed of almost the same constituents, with addition of another aluminous silicate, the hydromica, are mainly a combination of plagioclase feldspar with hornblende.

The proportions in the mixture of these two minerals are very variable; sometimes the plagioclase considerably prevails, other times the hornblende; oftenest both minerals balance each other approximately. The structure of these rocks varies from a fine, almost aphanitic grain to a very coarsely crystalline condition, in which both minerals are readily distinguishable by the naked eyes.

The plagioclase in nearly all these rocks is turbid, milky or transparent; portions are permeated with white, impellucid masses resembling in form lumps of curdled milk. Frequently the plagioclase exhibits not the shape of larger crystals but appears under the form of a minutely crystalline, granular, interstitial mass; sometimes however even this granular, interstitial plagioclase mass is under the microscope seen to be combined into larger crystal individuals not noticeable with the unarmed eyes on account of their turbidity and curdled interior. Only exceptionally the plagioclase crystals are in the condition to show their twinned structure by striation and chromatic polarization under the microscope.

The hornblende in all these rocks has a green color, lighter or darker. It is always more or less inclined to a fibrous structure; its facets therefore have never the smooth lustre of a mirror, like for instance the hornblende of the basalts, but it is a satin lustre; often also the lustre is very dull. It rarely forms completed crystals; usually the crystals are terminating on both ends in a torn, brush-like manner, or they are densely interwoven so as not to allow a distinction where one individual crystal ends and the other begins. Most of it displays a strong dichroism under the polarizer, but in the lighter colored varieties the dichroism is sometimes scarcely perceptible. In some of the rocks the hornblende is partially replaced by an earthy green substance called viridite, or by a chlorite-like mineral, both of which are considered to be decomposition products of the hornblende. Almost without exception, a number of granules or of clusters of granular crystals of titan-iron are found disseminated through the dioritic rock mass and usually these clusters of impellucid black colored grains are surrounded by a bluish white semi-transparent mineral, titanate of lime, which is most likely resulting from decomposition of the grains of titan-iron. Sometimes the titan-iron is replaced by magnetite and then its surroundings are tinged rusty brown.

Dispersed clusters of little cubes of iron pyrites are found in nearly all the diorites; sparingly scattered grains of quartz often occur, and in many diorites epidote is an accessory constituent. It is sometimes in portions of the dioritic rock masses very abundant and probably is a secondary product of alteration, not an original constituent. In the same manner also calcspar enters into the composition of diorites; likewise hydromica. The latter mineral seems to be the product of a paramorphosis of hornblende. In one instance at least, I found a soft, silky hydromica-schist which crops out on the wagon road from Negaunee to Ishpeming in association with massive diorites, to have been an aggregate of interwoven crystals of hornblende which had decolorized.

These crystals having the characteristic cleavage of hornblende, when crushed by pressure of the fingers dissolved into fatty-feeling transparent scales corresponding in every respect with hydromica. As in most of the dioritic schists, hydromica largely enters into their composition. I am inclined to suppose that the schists so intimately associated with massive diorite belts are a product of their decomposition under circumstances favoring the schistose arrangement of the molecules, or to speak in more definite terms, are a modified form of these eruptive masses and do not represent former sedimentary deposits.

Besides these genuine diorites, which as above stated are largely prevailing over diabasic rocks, I found during the microscopical examination of a great number of specimens comparatively few, in which, besides the hornblende, also augite entered into their composition.

In some of them the hornblende and the augite appeared to be independent original constituents, but in others the augite seemed to have been the primary mineral which seemed to have suffered partial transformation into hornblende. In external aspect the augite-bearing diorites are not discernible from the others; their nature became only known to me after examination with the microscope. Of diorite specimens examined found to be augite-bearing, I mention the following localities where I found them: T. 47, R. 26, Sec. 10, near center and in the N. W. ¼ of the Sec.; T. 47, R. 26, Sec. 18., S. W. ¼ of S. W. ¼; T. 47, R. 26, Sec. 7, S. W. ¼ of N. W. ¼; T. 47, R. 26, Sec. 15, S. E. ¼ of N. W. ¼; T. 47, R. 28, Sec. 13, N. W. ¼ of N. W. ¼; T. 42, R, 35, Sec. 13, N. W. ¼ of N. W. ¼. The fine-grained dioritic rocks at or near Quiver Falls on the Menominee are all augitiferous; also the range of diorite running across the N. ½ of T. 40, R. 30. The hornblende in them appears to be the result of alteration of the augite. The five first mentioned localities are all not far apart in the surroundings of Negaunee. Whether these eruptive belts are contemporaneous with the other diorites or whether they are younger dykes intersecting them I have not been able yet to ascertain, for the above mentioned reason that the augitic character of the concerned rocks was not recognized by me while in the field.

Still more rare is the occurrence of gabbro, or plagioclase rocks in which diallage takes the place of hornblende or augite as in

the diorites and diabases. I have here reference to rocks supposed to be contemporaneous with the dioritic rock masses, and not to the gabbros above mentioned as eruptive belts much younger than the diorites, which latter, in some parts of Lake Superior region form whole mountain ranges.

In my previous report I described the rocks exposed at Upper and Lower Quinnesec Falls and those forming the barrier of Sturgeon Falls on Menominee River as diorites, relying on macroscopical examination of the coarse-grained varieties of these rocks which, according to Credner's and Pumpelly's statements, were diabases or gabbros.

Recent microscopical examination of these same rocks convinced me that I was in error with regard to the barrier rock of Sturgeon Falls which has the composition of gabbro, but the rocks exposed at Upper and Lower Quinnesec Falls are typical diorites. Portions of the barrier rock of Sturgeon Falls contain, besides the pale greenish gray diallage, also dark green strongly dichroic hornblende prisms; locally even the hornblende replaces the diallage altogether.

Below Sturgeon Falls other rocks of gabbro composition are largely exposed in Sec. 35 of the same town; they resemble the barrier rock by their white and greenish gray speckled appearance, but the magma of crystals is much more minute.

Several miles lower down on Menominee River, in the N. W. ¼ of Sec. 16, T. 38, R. 28, another gabbro belt occurred to me, which resembles an ordinary dark colored diorite, quite unlike in appearance to the barrier rock at Sturgeon Falls. Thin sections of the rock show its composition of about equal proportions of transparent prisms of plagioclase and of green colored most delicately laminated blades of diallage filling the interstices left between the plagioclase crystals. Diallage appear also as a constituent of certain beds of the serpentines which intersect the dioritic series in dyke form a short distance above Sturgeon Falls.

Exposures of a dark, blackish green massive rock, composed of an agglomeration of large blades of diallage with an interstitial cement of green colored serpentine are in the S. W. ¼ of Sec. 26, T. 39, R. 29, next to the road leading to Menominee; other quite fine-grained rock seams found in association likewise consist of a groundmass of serpentine crowded with minute scales of diallage. In rocks of minutely crystalline structure it is often difficult to make the distinction between hornblende and diallage, as the paler colored hornblende exhibits only a faint dichroism and has the same laminated appearance in thin sections as the diallage; the angle of intersection of the hornblende cleavages is also not always observable in the thin sections.

In the latter mentioned rocks of almost aphanitic grain, I based the determination of diallage in their composition on their intimate connection with the coarser crystalline diallage-bearing rock masses; otherwise the scaly leaflets had just as much resemblance to a light green colored hornblende. The rocks largely exposed in Sec. 12, T. 39, R. 30, are also mingled with diallage blades. The greenish gray, middling-fine grained rock consists of a groundmass of granular plagioclase in intermixture with large quantities of magnetic granules, besides interstitial patches of serpentine-chrysotile. Within this crystal magma numerous blades of diallage and clusters of olivine grains are copiously disseminated.

On page 219 of the previous report I gave a description of several coarsely crystalline rocks occurring on the Menominee River in T. 37, R. 28, Sec. 9, about three-fourths of a mile above Pemenee Falls, which were based merely on macroscopical examination, and require a correction after I examined thin sections of them under the microscope.

These rocks, found in the same locality, evidently represent two different kinds of eruptive masses.

The blackish colored rock of porphyritic structure, just described, is an augitic and not a hornblendic rock, as I had supposed. It is composed of a fine-grained groundmass of plagioclase, part of which is turbid, granular, part is transparent, exhibiting sometimes polysynthetic striation, but usually these transparent portions on revolution between crossed nicols become dark and light, but show no bright colors.

Within this groundmass are irregular, rounded, transparent grains copiously disseminated, which exhibit bright, chromatic polarization and are probably augite microlites; with them occur plenty of colorless apatite needles.

Other much larger transparent grains scattered through the groundmass in clusters consist of olivine; they are intersected by a network of capillary seams in which dustlike magnetite granules have accumulated; their color is pale yellowish.

Macroscopically visible are large augite crystals, perfect all round, often twinned and composed of concentric zones, one enveloping the other. In thin sections they are transparent, with greenish brown or yellowish color; they often inclose grains of olivine. Magnetite granules are abundantly disseminated through the whole mass, and small irregular dots of the rock mass are purple-colored from infiltration of ferruginous pigment.

The other rocks described on the same page as coarsely crystalline hornblende rocks, are of particular interest by the intimate combination of their hornblende with augite, which plainly exhibits all the gradations of the paramorphic process from augite into hornblende.

The freshest-looking of these rock masses consist almost exclusively of an agglomeration of brightly shining, dark colored hornblende crystals with only a small proportion of turbid white or cloudy reddish colored feldspar crystals in the interstices left between the hornblende crystals, besides some scattered blades of dark greenish colored biotite.

In thin sections the hornblende crystals are transparent with greenish brown or yellowish color, perfectly clear, homogeneous if the section is parallel to the cleavage, longitudinally striated if the section is vertical to the cleavage. The crystals enclose numerous clusters of grains of magnetite which often have a singular lobate or also horseshoe form, and very thin sections show these agglomerations of granules to be cemented by a transparent interstitial mineral.

In these fresh rocks only few of the hornblende crystals exhibit a dull greenish white blotch in the center, which under the microscope discloses itself as almost colorless augite intersected by a network of capillary seams, from which emanate fibres of faintly green colored hornblende piercing the transparent augite mass; besides there are also scales of dark colored homogenous hornblende lodged between the augite mass so as to be in correspondence with the cleavage of the exterior hornblendic shell of the crystal.

Other portions of the same rock belt are dull, little reflecting the light, and appear to be in a more or less advanced state of decomposition. On close inspection the main mass of the agglomerated crystals is formed of the above described pale greenish colored seamy augite, permeated by blades of dark green hornblende, so arranged as to reflect the light simultaneously in certain positions corresponding with the angle of hornblende, while at the same time not rarely the almost rectangular prismatic form of the original augite crystals is observable.

The transformation of the augite into hornblende proceeds in different modes, the most regular of which consists of a uniform alteration of an augite indivual from the periphery toward the center into a single homogeneous hornblende crystal, where the peripheric part becomes first completely changed into dark colored, brightly shining hornblende substance, which gradually infringes on the central, almost colorless kernel of augite by pushing its sharply defined lobate projections deeper and deeper into the mass, which shows the first signs of alteration by assuming a pale grass-green color and a fibrous structure in parallelism with the finished exterior shell of the crystal, while isolated fragmental blades of dark colored hornblende form also centrally, which enlarge on their margins and finally coalesce with the outer part into one large cleavage plane of the crystal.

In other instances the hornblende commences to form in interwoven needle-shaped prisms permeating the augite in radiating clusters, which process does not result in the production of one crystal individual imitating the shape of the original augite crystal, but terminates into an agglomeration of hornblende fibres.

A portion of the uralitic rocks is further advanced in alteration by transformation of the augite into an earthy hematitic substance, which alteration attacked only part of the crystals, leaving the others intact. The very fresh aspect of the rocks formed of hornblende free of augite, and the dull, easily disintegrating condition of the augite and hematite portions irresistibly impress the observer with the idea of the primary existence of the first and the derivative origin of the latter, but after quiet consideration one can very well conceive the rotten appearance of the original augitic material and the freshness of the product resulting from its decomposition. I was under such erroneous impression when, on page 213 of the previous report, I stated the intimate intermixture of very fresh tremolite crystals with more or less decayed crystals of sahlite, and inferred the sahlite to be an alteration product of the tremolite.

The extension of the survey into the Gogebic district showed to me a perfect analogy in the structure of the Huronian series with the Marquette or the Menominee region.

North of the granite range previously mentioned, in many, but not in all localities, a large body of schistose and massive dioritic rocks overlies it, dipping to the north, and forms the base on which the iron-bearing rocks repose. More rarely the dioritic rock belt is found missing and the iron rocks follow immediately above the granite. The dioritic rock group there amounts to a considerable thickness. Most of the diorites are fine-grained, and some of them very light colored, almost totally composed of granular plagioclase; rocks of this kind are largely exposed along the north line of Sec. 23, T. 47, R. 44. Associated with singular compact rock belts of coarsely brecciated structure composed of large and small angular blocks of various kinds of diorite cemented by a seamy interstitial mass very similar in composition to the inclosed dioritic fragments, numerous milky plagioclase crystals of large size, or also rounded concretionary nodules of feldspar have segregated in it. Calcspar likewise sometimes enters freely into the composition. The cementing groundmass exhibits a distinct fluidal structure, as if the rock fragments had been stirred into it while it had the plasticity of a dough. The fresh-fractured rock resembles a compact porphyritic diorite, as the color of the rock fragments and their cement do not differ much, but on the weathered face of the rock the brecciated composition and the fluidal structure of the cement mass become very obvious.

Large bluffs of the same kind of breccia are also exposed on the side of the trail near Mr. Gillis's camp in T. 47, R. 43, along the north line of Sec. 23; it forms there the footwall of the galena-bearing quartzite formation, the lowest beds of which are a coarse conglomerate of quartz pebbles of various color. South of these outcrops a large succession of massive and schistose dioritic beds follow, then granite follows in close contact with them.

Near the south end of Gogebic Lake and east of it, in T. 46, Rs. 42 and 41, other large exposures of dioritic rocks occur, which dip in an opposite direction southward; they are conformably overlain by an ore-bearing sedimentary rock series. The eruptive nature of the diorite is proved by the occurrence of belts cutting transversely through the ore-bearing rock series in the vicinity. North of the diorite, according to their southern dip, exposures of the lower granitic rocks should be expected, but none are visible, as all the surface in that direction is covered with drift deposits. Two miles north of the diorite outcrops, after passing over a belt of lowlands, a range of hills rises which is formed of steeply erected ledges of the copper-bearing diabase, dipping north; it commences in the south part of Sec. 30, T. 47, R. 41, and extends eastward, as I am informed by explorers acquainted with this region, for about 30 miles without being much interrupted. This is the so called South Trap Range.

It was at first my intention to give at the end of this chapter a detailed description of all the microscopically examined rock specimens of this group, but after writing such descriptions, I saw they necessarily involved an endless repetition of nearly the same facts. As the specimens amounted to over two hundred, I discarded this plan, too tedious for the reader, and refer those who would have an interest to know the results to the museum of the University of Michigan, where the sections and hand specimens appertaining to them are deposited.

CHAPTER IV.

IRON ORE GROUP.

(A) MARQUETTE REGION.

In the former report I designated with the above name the strata succeeding above the dioritic group, as they inclose the rich deposits of specular and magnetic ore found in the Marquette district. This name has become ambiguous since the discovery of equally large and perhaps larger deposits of iron ore in higher horizons of the Huronian series, and should be amended into "Lower Iron Ore Group."

Reviewing the old established mining district between Negaunee and Lake Michigamme, I find during the time passed since the publication of the last report many discoveries made concerning the local extent of the ore-bearing beds; in particular has been demonstrated by facts the uninterrupted extension of the northern belt of the synclinal trough of ore deposits from the Excelsior mine westward beyond the west line of T. 48, R. 28. From a number of new mining pits opened on that belt at present a very good quality of specular ore is sent to the market.

No new facts however which would essentially alter the previously delineated structural features of the formation have to be reported.

In some places east of the Boston mine the strata which have in that mine a dip to the south are perfectly tilted over and dip northward, the younger beds occupying positions below the older ones, which excessive local dislocation appears to be caused by the eruption of doleritic rocks largely exposed there in dykes intersecting the ore-bearing beds. The superficial portions of these doleritic masses are in a friable decomposed condition representing a white and brown speckled absorbent kaolinitic mass in which the external shape of the former plagioclase and augite crystals is yet preserved. The occurrence of a similarly decomposed dolerite belt on the Jackson mine property near the south line of S. E. ¼ of Sec. 1, T. 47, R. 27, associated with the manganiferous hematite ore deposits is noted on page 76 of my former report.

By recent explorations at the foot of the knobs northeast of the Negaunee iron furnace, the same doleritic rock, but in perfectly fresh condition, has been struck by a shaft and was at first by the miners erroneously taken for a representative of the quartzite in the hanging of the specular ore deposits; further sinking in the rock soon proved the mistake.

I owe yet the description of a number of mining locations on the Michigamme river north of the Republic mines, which at the time of the publication of the previous report I had not examined; all of them were also then abandoned.

Subsequently several parties undertook to re-explore these grounds, partly by test-pits, partly with the diamond drill, which work was a great help for me in the study of these localities. The results of these explorations were, at the present depressed condition of the iron market, not considered favorable enough to resume in any of the examined places actual mining operations, although in several of them a good quality of bright specular ore resembling that of the Republic mine was found.

Holding detailed review of these localities in going from the Republic mine up the river road, we meet, past the Kloman location, which has been described before, a number of exploring trenches and shafts in the N. E. ¼ of Sec. 2, T. 46, R. 30, in which, under a cover of drift several feet in thickness, quartz-banded specular lean ore beds dipping in an almost vertical position northeastward are found, which from time to time inclose, in the alternation of seams, larger lenticular masses of apparently pure specular ore and likewise thick heavy beds of quartzite. Close examination of these bright ores proves them, however, to the greatest extent so much contaminated with quartz grains that their market value is very small and mining operations were therefore discontinued.

Farther on, in the S. W. ¼ of Sec. 35, and the N. E. ¼ of Sec. 34, T. 47, R. 30, the hillsides to the left of the road present large exposures of dioritic rocks in brecciated intermixture with fragmental masses of well laminated garnetiferous mica-schists

of dark geen color and with other schistose rock fragments of chloritic, actinolitic and quartzose feldspathic nature. At the same time, dykes of a coarsely crystalline granite frequently are seen to intersect the brecciated dioritic rock belt.

In the N. E. ¼ of Sec. 34 is the abandoned Winslow mine, on which location a jasper-banded lean ore belt in a vertical position crops out in close contact with granite bluffs. A deep shaft is sunk into this vertical banded lean ore belt which, as could be expected beforehand, remaining in the same beds all the time, proved to be a total failure.

Next north we come to the likewise abandoned exploring pits of the Standard Mining Company, which employed the diamond drill on their explorations, besides digging test-pits. The banded lean ores in association with compact quartzite belts and with highly micaceous silvery shining quartz-schists, are the beds seen in the exposures. Small seams of good specular ore of slaty structure and of a very compact fine-grained steel-colored ore were met with in the banded ferruginous part of the series, but it does not appear in quantities great enough to be mined profitably.

Proceeding further north on the river road, we pass over drift-covered terrace lands bordering the river, with bluffs of dioritic rocks associated with garnetiferous, actinolitic mica-schists, visible a short distance to the left of the road. In the N. ½ of Sec. 28 we leave the river side and ascend by a path the hill on which we find the Cannon and Erie mines located. The Erie mine comprises the N. E. ¼ of the N. W. ¼ of Sec. 28; all the remainder of the section is Cannon property. The openings of both mines are close together on the dividing line between the properties. The general trend of the strata is from southeast to northwest; dip under a high angle northeast. The succession of beds in descending order is as follows: First, forming the upper part of the slope towards the river, a succession of heavy, light colored, whitish, quartzite beds interstratified with thinly laminated micaceous quartz-schists and with seams of soft mica-schist of great silvery lustre is exposed or found under a thin cover of drift masses. The thickness of this belt is about 200 feet.

Next below succeeds a dark colored rock belt with metallic lustre, about 80 feet wide, consisting of alternate narrow bands of granular or jaspery quartz, red or dark gray colored by impregnation with hematitic pigment, and thinly disseminated specular ore granules, and of other bands almost entirely composed of ore granules with a smaller proportion of quartz grains intermingled. Locally these ore seams widen into large lenticular masses of specular slate ore; in some of them, however, a portion of the mica-like scales of the ore are replaced to a great extent by true mica. A similar transition of slate ore deposits into mica-schists comparatively poor in iron is also observed in other locations, as for instance in the western pits of the Washington mine.

Beneath this iron-bearing rock belt follows a large series of light colored mica-schists of great lustre, partly in soft fatty-feeling layers, partly hard and gritty by admixture of granular quartz, particularly in the lower horizon where the quartz predominates. Finally the schists are succeeded by compact quartzite beds, which latter layers are locally shattered into fragments and with intermixture of other quartzose, dioritic, and granitic rock pieces are re-cemented into a very coarse breccia, which encloses also rounded concretionary masses formed of hornblende crystals, which concretions gradually merge with the surrounding quartzite plasma by plentifully dispersed single hornblende prisms in their circumference becoming more and more distantly scattered in proportion with their remoteness from the concretionary nucleus of hornblende. These beds are well exposed on the dividing line between the two mines and are at the same time seen in contact with an eruptive diorite belt which crosses the strata transversely and, probably, caused by its eruption the great disturbance and shattering of the beds. We see in the mining pits opened there large segments of the banded lean ore belt, of mica-schist, micaceous quartz-schist and of actinolite-schists impregnated with magnetic ore in irregular hap-hazard position intermingled, with retention of the stratified order of the individual segments of the rock belt; interstitial between them is a network of tortuous bands of garnetiferous dark green colored mica-schist, which, together with branching dykes of the diorite, make the chaos complete.

Some distance further west in other pits of the Erie mine a little less disorder in the relative positions of the beds is observed; still, the dislocation and confusion of the strata are yet so great as to interfere seriously with the mining according to a systematic plan. Serpentine plications and unexpected faulting of the beds are a constant annoyance for the miner, and also considerably increase the expense of mining.

A few hundred steps south of the mining pits a row of granite bluffs is seen to follow the trend of the formation. North of the pits is a low ridge of diorite striking east and west, obliquely intersecting the ore-bearing strata. The before mentioned dioritic rock associated with the greatly disturbed beds in the mining pits on the line between the Erie and Cannon mines forms a side branch of this larger diorite belt.

The present exploratory work of mining at the Erie location had the success of demonstrating the occurrence of lenticular seams of specular slate ore and others of a granular magnetic ore within this rock series sufficiently large, as it appears, to be profitably mined. The large ore piles hoisted there look as bright as the best ore of the Republic mine, but it is on close examination much more contaminated with silica, and only part of it ranges as first-class, high-graded ore. The above mentioned frequent occurrence of faults or abrupt plication of the strata is a circumstance making mining operations uncertain in that locality and has to be considered in estimating the value of the location. On the east side of the river opposite the Cannon and Erie mines, in the S. W. ¼ of Sec. 22, T. 47, R. 30, is the Chippewa mining property, where in former years considerable exploring work had been done, not with the expected favorable results, however.

Starting from the Erie mine, after having crossed the river and an adjoining drift-covered elevation, we find on a second low ridge exposures of a large succession of quartz-banded lean ores interstratified with silvery shining, minutely scaly mica-schists, and beneath them follows a broad belt of garnetiferous mica-schists, some layers fresh, dark green colored, smoothly laminated, or elsewhere much twisted and corrugated; other strata are in a decomposed condition, lighter brownish colored and the enclosed garnets changed into a rusty, friable, earthy mass.

Underlying these succeeds a wide belt of light colored, thick-bedded, more or less micaceous quartzites, and further east, after interruption of the outcrops by a narrow, swampy depression, we find gneissoid and granitic rocks intersecting each other in transverse belts to form the general surface rock.

The strata have a southwest dip in synclinal opposition to the strata of the Erie mine, but do not seem to represent the synclinal counterpart of them; as compared with them, their succession is in inverted order; the large quartzite belt supposed to be the equivalent of the quartzite overlying the beds of the Erie mine is here lowest, and the ore-bearing beds rest upon it. A perfect overturn of the series, therefore, suggests itself. No larger seam of high-graded ore worth mining has been discovered in this locality.

The hitherto described ore-bearing rock belts all seem to be analogous to the layers of the Republic mine.

Returning to the west side of the river, we find at a distance of about a mile and a half northwestward and a half mile off from Michigamme River, another mining location called the Magnetic mine (S. E. ¼ of N. W. ¼, Sec. 20, T. 47, R. 30), where, at the time of my visit, a diamond drill was at work on the drift plateau next to a range of hills on the west side, about 60 feet high.

The cores of the drill, which had reached the vertical depth of 400 feet, showed so far the penetration of dark green micaceous hornblende rocks disseminated in some levels with an abundance of red garnets and intermingled with streaky seams richly impregnated with magnetic ore granules. The ridge on the west side of the drill hole consists of the same kind of hornblende rock.

The obscurely stratified rock masses dip under an angle of about 45 degrees to the north. On the summit of the ridge the strata break off abruptly, and on the west side a stairlike descent is made into the narrow valley of a small creek, where next underlying the hornblende rock compact micaceo-feldspathic ledges follow. Below them are dark green colored schistose beds consisting of brightly shining biotite leaves in intermixture with rather large brownish red garnet crystals.

These are conformably succeeded by a very large succession of well laminated, banded quartzose, actinolitic layers, richly impregnated with magnetite, which inclose larger and smaller seams of magnetic ore locally widening into pockets sufficiently large enough to invite mining operations. The thickness of this succession of actinolitic beds is not less than about 800 feet. The ore masses in the pockets are intersected by seams solidly

filled with interwoven crystal blades of bright green hornblende associated with large brown garnet crystals, with quartz and calcspar, and with nests of tungsten (wolframate of lime), a mineral which to my knowledge never was found before in any of the mining localities of Lake Superior. West of the Magnetic mine extensive explorations for the same ore deposits are in progress near the quarter-post on the east line of Sec. 19, in which place the succession of beds below the ore-bearing strata is better exposed than on the Magnetic mine. These lower beds are well laminated micaceous quartz-schists of silvery lustre, similar to those resting on the ore-bearing rock series of the Erie mine, and amount to a thickness of from 700 to 800 feet. The lowest bed of the series is a compact ledge of quartzite which rests immediately on granite. Other exploring work has been done in the south part of the N. E. ¼ of Sec. 20, T. 47, R. 30, by the same parties who opened the Magnetic mine. We find there the same rock series exposed as in the other two localities, but as this place compared with the location of the Magnetic mine, situated in the S. E. ¼ of the N. W. ¼ of the same section, is much farther to the north, the formation must have been subject to a faulting of many hundred feet intermediate between the two mining openings.

Going from the last mentioned mining pits across the strike of the formation northeastward, I found after passing some distance over drift-covered lands near the northeast corner of the section, a row of knobs about 50 feet high, which consisted of vertically erected beds of the typical staurolitiferous mica-schists striking in a direction approximately north and south. The staurolite occurs in these mica-schists rarely in the form of well defined crystals, but in lenticular concretions often as large as a hen's egg. Breaking them, their grain is not homogeneous, like that of a crystal, but holding the fracture in a certain direction to the eyes the grains of the substance reflect the light all simultaneously, with great lustre. Under the microscope an aggregate of brownish colored and colorless grains with chromatic polarization is noticeable, the exact nature of which I have not determined, excepting the fact that no quartz grains make part of this mass; the colorless grains break the light all at once in the same way, changing in revolution under the polarizer their color into indigo blue, but not running through any other color, except a darkening. At the northwestern corner of the same section a large body of crystalline rocks, which have a laminated gneissoid structure, forms a cluster of knobs; the strata have a northern dip conformable with the ore-bearing beds at the Magnetic mine, from which they are separated by an intervening drift-covered space. They consist mainly of a groundmass of feldspar crystals, probably othoclase, and of fibrous blades of green hornblende with some biotite scales intermingled; the feldspar much exceeds the hornblende in quantity. These rocks hold an intermediate position between the staurolitiferous mica-schists exposed at the northeast corner of the section and the strata of the Magnetic mine; they are altered sedimentary rocks, as well as the next lower belt overlying the ore-bearing beds of the Magnetic mine, which latter, by their massive crystalline form, have much resemblance with eruptive rock masses. Thin sections of the latter rock examined under the microscope show its composition of a mixture of quartz and feldspar grains with about an equal quantity of interwoven lacerated prisms of green hornblende, besides scattered biotite scales and more or less abundantly disseminated magnetite granules. The ore range on which the Magnetic mine is situated describes an arch trending from the mine, first west toward the quarter-post on the east line of section 19, and thence southward to the center of section 31. Inside of this arch are several granite hills. The ore of the Magnetic mine resembles the ore of the Michigamme or that of the Spurr mine.

Analysis of select specimens of the ore gave 65 per cent metallic iron; 9 per cent were impurities, principally quartz grains and mica scales; the amount of phosphorus is small.

Large burrows of ore are piled up at the mine, but to my knowledge none has ever been sent to the market from this place and work is suspended in it since several years.

These ore deposits are younger than those of the Erie or of the Republic mine. The higher position of the ore beds of the Magnetic mine than those of the Erie mine is directly traceable by following the outcrops of micaceous silvery shining quartz-schists which underlie the ore-bearing actinolite-schists of the magnetic mine, in the direction of the Erie mine, where we will find the same micaceous schists in the hanging of the Erie mine rock series.

The magnetic ore of the Michigamme and Spurr mines occurs likewise in a lower horizon than that of the Magnetic mine, but the actinolitic rock belt succeeding above the actually mined beds of these locations, corresponds in its relative position and in its lithological character fully with the group of beds disclosed at the Magnetic mine.

On special comparison of the mentioned localities I found to my surprise a discrepancy in the succession of beds which I could not explain, considering that the distance between the compared localities is only a few miles.

The case is: South of the actinolite schists at the Michigamme mine I saw, in conformable position succeeding, a large complex of ferruginous cherty beds interlaminated with seams of limonitic ore and with graphite schists, and farther south outcrops of a succession of mica-schists in conformable position with the former; did therefore not doubt then for a moment the interstratification of this belt between the actinolite-schists and the higher mica-schists. On the other hand I found, in the succession of beds above the Magnetic mine, the mica-schists to be the next, without a trace of an intervening rock series comparable to that in the other place, more than a thousand feet in thickness.

Farther inquiry taught me that there was no anomaly in nature, but that my observations were imperfect and misled by the theoretical notion which I had with regard to the position of the so called mica-schist formation, thinking it to be the uppermost complex of sediments in the Huronian series, in accordance with Major Brooks's views.

The actual state of things is: The mica-schists are the next succeeding layers above the actinolitic rock belts of the Michigamme mine and of the Magnetic mine; the large series of graphite schists and limonite-bearing cherty beds are younger deposits conformably resting on the mica-schist series, which is well developed on the south side of the actinolitic belt at the Michigamme mine, but which had previously escaped my observation, as the limited outcrops of these dark colored mica-schists crowded with red garnet crystals, seen near the track of the H. & Ont. R. R., were considered by me as a subordinate seam of the actinolite-schist belt underlying the limonite-bearing group, as I saw the large body of mica-schists presenting itself almost a mile farther south, seemingly overlying these graphitic and limonitic rocks which actually lie wedged in between a fold of the mica-schists. The northern side of this synclinal fold is hidden under a deep cover of boulder drift, but space enough is left for a wide belt of the schists, as the first indications of the presence of the overlying rock belt are over half a mile south of the exposures of the mica-schist, on the railroad near Michigamme village.

As I intended to retain in this report the stratigraphical order observed in the previous volume, the above description should have been given in the succeeding chapter, but it is sometimes unavoidable to deviate from this plan, if localities have to be described in which an extensive series of rock beds is displayed.

Before proceeding to describe the progress of the examination in the iron districts of Felch Mountain and in the Gogebic Range, I have to mention yet certain peculiar rocks found in association with the iron ore at the Washington, Edwards and Champion mines; at the Spurr mine and Michigamme mine similar rocks are found in large blocks among the loose rock masses covering the surface, but to find them in place there I could not succeed.

The principal compound of these rocks is a dark green colored, large-leaved mineral, with a bright pearly very perfect cleavage in one direction, brittle and of the hardness of feldspar, which I supposed to be hypersthene, but was afterwards informed by Prof. J. D. Dana of its identity with chloritoid, as it perfectly decomposes on treatment with concentrated sulphuric acid, which does not act on hypersthene.

In the eastern pits of the Washington mine and likewise in the Edwards mine an almost black crystalline rock occurs next above the productive ore seam, which consists of an agglomeration of coarse blades of this mineral with a small proportion of reddish feldspar crystals and of hydromica filling the interstices; here and there are also clusters of prisms of black tourmaline and scales of dark green biotite, which latter are also found penetrating the substance of the chloritoid crystals.

This variety of the rock resembles in its structure an eruptive mass, but in intimate association with it are other well laminated schistose beds, in which the chloritoid crystals are distantly scattered, the sedimentary origin of which beds is unquestionable. These schists consist of silvery soft hydromica, copiously mingled with dustlike magnetic granules, in which very much wrinkled and corrugated groundmass large blades of the chloritoid, more than an inch in length and half as thick, are irregularly imbedded.

This schistose form of the rock is not so common in the Washington and Edwards mines, but it forms a large belt adjoining the ore of the Champion mine.

The loose blocks found south of Michigamme village and on the north side of the railroad between the Michigamme mine and Spurr mine, are quite large, several of them are 10 feet high and 20 or 30 feet long. They consist of a mixture of dark brownish hexagonal biotite blades about one millimeter in diameter with an equal proportion of white hydromica scales and disseminated magnetite granules, in which groundmass lentiform concretions of the chloritoid are distantly imbedded, or locally also larger masses of it are found crowded together. These biconvex lentils, often over two inches wide and in the center three-quarters of an inch thick, have a continuous cleavage, which, if practically possible without breaking them, could be split according to their curved cleavage seams into an inclosed set of disks, like watch glasses; the transverse fracture of the crystalline masses is dull, lineated in the direction of the cleavage.

At the Champion mine, with these chloritoid-bearing hydromica-schists, other rocks with a groundmass of hydromica occur, which at a distance resemble a coarse-grained variety of the above mentioned groundmass of the loose blocks holding chloritoid, but the biotite blades in that are, in this rock, represented by small reddish brown colored, semi-transparent, tabular orthoclase crystals.

(B) MENOMINEE REGION. 1. FELCH MOUNTAIN RANGE.

In regard to the iron-bearing rock series of the Quinnesec Range, I have nothing of importance to add to the previously given descriptions.

Explorations on the range were constantly going on and have led to the discovery of some new localities promising to be valuable for mining. On the other hand some of the older mines became exhausted, and probably more of them for that reason will have to be abandoned, if meanwhile no new deposits should be found besides those presently in sight.

The great anticipations of inexhaustible ore deposits in the

Felch Mountain district have likewise not been fully realized, although some of the opened mines promise well.

From the former descriptions I gave, it will be remembered that the strata of the iron-bearing group in the Felch Mountain Range dip under a high angle northward and consist of the following succession of beds:

The underlying rock of the iron ore formation is always formed of crystalline rocks, granite or diorite. The lowest strata are generally heavy, light colored quartzite beds, with interlaminated thinner ledges and schistose seams, amounting to considerable thickness.

Above this belt an equally large succession of well-laminated, even-bedded, often fissile, slate-like micaceous quartz-schists follow, which have a great silvery lustre. Next above them comes a series of micaceous argillites amounting to a belt even larger than the former, which varies greatly in shades of color, firmness of grain, etc.; some layers are whitish, others gray or bluish and greenish, but the greatest portion of them is intensely red colored by hematitic pigment. A part is a fatty impalpably fine mass of silky or also pearly lustre, according to the size of the mica scales incorporated with them. Another part is rough and gritty from the prevalence of arenaceous constituents.

At this horizon and rather in the lower part of it occur locally large bodies of crystalline limestone ledges, some snowy white like Italian marble, but of coarser crystalline grain and intermingled with radiating clusters of asbestine fibres and larger prismatic crystals of colorless tremolite, which sometimes forms larger concretionary seams in the lime-rock, and are then intimately associated with crystal masses of sahlite, one mineral penetrating the other in a manner which suggests either a process of paramorphosis in progress, changing the sahlite into tremolite, or the original conditions, when the calcareous material combined with the silica by a slight modification, induced simultaneously the crystallization of the almost identical chemical combinations in one and the other form; which latter suggestion is more sustained by the actual condition of the mingled minerals than the first, as some of the crystals of both minerals tightly grown together are so perfect in form peculiar to each and so sharply defined that they must be considered as crystal individuals which formed side by side and altogether independent

of one another. In other localities where such crystalline limestone belts occur, the tremolite is only sparingly intermingled, but in its place colorless mica scales of nacreous lustre are plentifully disseminated.

In the place of marble-like limestone sometimes also ordinary lime-rock of dull aspect with conchoidal fracture, and variously tinged, occurs; it is then usually full of flinty siliceous seams, resembling the limestones of the Quinnesec range; the quartzose seams locally even prevail over the calcareous. Incumbent on the before mentioned micaceous argillites succeeds a belt, about 800 feet in width, composed of thinly laminated banded ferruginous quartzite ledges of dark purplish tints or having a metallic lustre from intermixture of specular ore granules. The banded portions are formed of an alternation of narrow seams of specular ore with siliceous seams not so richly impregnated with the oxide. Other strata in the succession are porous cherty rocks charged with ochreous yellow or brown oxide of iron and enclosing pockets of the limonitic ore. Also blood-red argillitic seams occur in the succession and with them sometimes pockets of soft crumbly hematite ore.

Within the first mentioned banded alternation of narrow ore seams with quartz seams, larger deposits of specular ore in slaty or in compact granular, or also in the soft friable condition of the so called blue ore of the Quinnesec mines occur, which constitute the principal storage of ore sought for by the miner, besides the hematitic and limonitic deposits mentioned before. The first impression of every observer examining this above described rock series will induce him to consider it as an ascending succession, as the layers follow one another in apparent conformity, but in some localities, after having crossed this succession so far, if we proceed farther in the same direction, we intersect the same series again in an inverted order, but retaining the same dip, until we have reached again a large belt of compact quartzite ledges in close contiguity with granite or also diorite, as it may happen, which latter rocks then form the surface rock of large areas on the north side of the Felch Mountain ore formation. Several localities in which these observations can be made are on the north line of Sec. 31, T. 42, R. 28; likewise in Sec. 31, T. 42, R. 29, and also at the quarter-post of the west line of Sec. 28, T. 42, R. 28. At the latter locality, however, the exposures are interrupted

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by horizontal Silurian sandstones resting on the top part of the hills.

The only satisfactory explanation which I can give of this repetition of the rock beds in an inverted order, is the suggestion of a folding of the beds and the overturn of the fold by a pressure acting principally from the north side. If this is the case, we would have to consider the light colored quartzite next to the granite as the most recent deposits and the dark ore-bearing banded quartz beds as the oldest, which would bring the structure of the Felch Mountain ore formation in perfect harmony with that of the Quinnesec ore range.

The limestone described on page 202 of the previous report as occurring interstratified with the banded ore-bearing beds on the slope of the hill near the center of Sec. 31, T. 42, R. 29, is a detached mass wedged in between a fold of the ore-bearing beds during the upheaval and in this way escaping destruction by the erosive forces which swept off the balance of superficial rock masses.

Likewise are the limestones south of the Metropolitan mine, mentioned on page 196, loose outliers, entangled between the ore-bearing beds. These quite large masses are disposed in several parallel rows trending east and west; the position of the ledges is nearly vertical, and no one seeing the outcrops would suspect them to be loose masses, if it was not for the work of the explorers for iron. They dug in various places test-pits into the ferruginous beds at the base of these limestone crests, on one side and finally came out on the other side without ever having touched the limestone, constantly remaining with their tunnels in the iron-bearing beds. Several hundred steps south from there similar limestone masses are found in direct contiguity with granite. Another mass of limestone, most likely also not in place, was struck on the north side of the pits of the Metropolitan mine. During the exploration of the property with the diamond drill, the boring commenced in dark red colored micaceous argillites and from next under them a snow white crystalline limestone came out in the cores. Judging from the quantity of cores left near the drill hole, the belt of limestone must have been very thick.

The ore-bearing formation in T. 41, R. 28, two miles south of Felch Mountain, belongs to the same horizon as the ore beds of the latter. Natural exposures are not so extensive as there, as the greater part of the surface is covered with drift masses and underlying horizontal Silurian sandstones.

In test-pits opened in Secs. 17 and 18, by Mr. Brotherton and others, the strata dip to the north and follow each other in the same order as on Felch Mountain; farther south are light colored compact quartzites; above them a wide belt of micaceous argillites follows, which are intensely impregnated with hematitic oxide and from time to time interstratified with quartzose beds likewise deeply ore-tinged. North of the argillitic belt the wide series of jasper-banded lean ores succeeds, which, like in other places, locally encloses pockets of the soft crumbly blue ore, also red hematite ore, but none I observed large enough to promise great value to the miner.

Farther north we leave the jasper-banded ore belt, crossing a swampy depression with no exposures in the south part of Secs. 8 and 9, but on the other side of the depression a ridge parallel with the other rises, which is found to be composed of the same iron-bearing strata as the former ridge, but succeeding in an inverted order and dipping to the south. First comes quartzite, beneath it the micaceo-hematitic argillite belt, then follows the large body of jasper-banded lean ores in a much broken corrugated condition. It projects in steep bluffs on the northern brow of the hills, at the base of which red colored ferruginous argillites are denuded in test-pits; still lower in the embankments of a creek, dark green schists come to the surface and across the creek granite bluffs are close by.

Extensive explorations in Secs. 8 and 9 have led to the discovery of rich pockets of the blue ore, but the greatly disturbed, faulted condition of the beds is a great obstacle, preventing a systematic plan in mining and making the extraction of the ore more expensive. This southern ore formation has only been traced for the length of a few miles.

The Felch Mountain Range has been traced east of the Metropolitan mine for five miles, but so far no valuable ore deposits have been found in that direction. Westward the belt has been traced, with some short interruptions, to the Menominee River, north of Badwater village.

On this whole interval, besides the pits already mentioned, many others have been opened which exhibit an immense amount of low-graded mixed ore, but no large deposits of the better high-graded quality.

In the exploring pits of Mr. Breitung in T. 41, R. 30, N. E. ¼ of S. E. ¼, the succession of beds is as follows: Farthest north, bordering a swamp, a row of bluffs from 15 to 20 feet in height trends across the center of the section from east to west, which consists of nearly vertical ledges of a dark colored quartz-rock banded with seams of bright specular ore in alternation with the quartzose seams; their dip is northward. South and conformably underlying this belt succeeds a large series of sericitic or micaceous schists of silvery luster, red tinged by rich impregnation with iron oxide; farther south crystalline limestones follow full of asbestine fibres and at the same time of pearly shining scales of colorless mica. Interlaminated with the marble-like lime-rock many quartz seams occur, and in a still lower horizon a large body of heavy light-colored quartzite beds terminates the exposures and they project in vertical bluffs near the summit of the ridge, the top of which spreads out into an undulating drift-covered plateau.

According to the previously proposed theory the strata in this locality are in an overturned position, which seems to be most generally the case in the entire range.

2. MENOMINEE AND MICHIGAMME RIVERS.

The iron-bearing rocks found between the mouths of Michigamme and Paint Rivers into the Menominee, on the Wisconsin and on the Michigan side, differ from the Felch Mountain rocks and are of later date, probably contemporaneous with the ores of the Commonwealth mine and those of the Northampton mine in the Michigamme district; perhaps even they might represent the oldest beds of the mica-schist group, which is well developed in the immediate vicinity thereof.

In the N. W. ¼ of Sec. 17, T. 41, R. 31, Mr. Bordman made explorations in these iron-bearing beds. He began to dig test-pits in the large body of micaceous schists interlaminated with quartzose seams, of which I gave a description in a former report. Some of these beds are light colored, gray or greenish, but others are intensely red colored by hematite, so as to resemble a soft hematite ore where this impregnation reached a certain degree, but good real iron ore did not occur in association

with them. He found, however, in the lowest position right on the surface of a superficially decomposed diorite belt underlying these beds, and in clefts of the diorite, pockets of a compact hydrated iron ore, which to all evidences has been a secondary deposit of infiltration a long time after the deposition of this schistose series.

Under entirely similar conditions iron ore occurs on the opposite side of Menominee River at the abandoned Ellwood mines. The ore there also forms an incrustation on the surface of a decomposed, crumby diorite mass and fills crevices in it. The mica-schists exposed at the mouth of Paint River and down stream, which I will specially describe below under the heading of mica-schist formation, are in most intimate stratigraphical and lithological connection with the schists on both mining locations. At the Ellwood mine a part of the schistose beds is graphitic, also otherwise a great similarity of the entire group of beds with the schists exposed in the environs of Keyes Lake is obvious, which latter represents a part of the rock series enclosing the Commonwealth mine ore deposits. Another isolated patch of ferruginous deposits which attracted the explorers in this part is found a short distance below Badwater village in a ravine between two ridges of diorite in the N. E. ¼ of Sec. 31, T. 41, R. 30. It consists of a series of nearly vertical beds of calcareo-actinolitic composition which enclose a large proportion of coarse granules of magnetite of octahedric form. Adjoining the beds are well laminated, dark colored chloritic schists in conformable position with the others, then on both sides of the ravine massive diorite crops out. Considerable work was done to uncover these beds, but no merchantable ore was found, and even if it was, the deposit is too limited to be of value. The age of these actinolite beds I think corresponds with the actinolitic layers of the environs of Keyes Lake, subordinate to the Commonwealth ore formation. To the same geological horizon belong the ore-bearing strata uncovered by explorers on both sides of the Michigamme River north of Lake Mary, in Sec. 5, T. 42, R. 30, and in adjoining sections. There is quite a large succession of micaceo-ferruginous argillite-schists interlaminated with quartzite seams and jaspery banded beds, which enclose concretionary masses of limonitic ore in the form of crystalline grape-ore, and in amorphous, earthy or compact form; these beds repose in steep inclination on a substratum of diorite, which, in association of granite, is the general surface rock of this part of the country.

Eight miles farther north, in T. 44, R. 31, Secs. 33 and 34, near Michigamme River, Mr. Brotherton made explorations in iron-bearing rocks which correspond in age with the Quinnesec ore range, and cover there quite an extensive area.

In Sec. 33, on the north side of the exploring pits, we find a ridge of schistose and massive diorite which is intersected by dykes of diabase which locally are found in a friable decomposed condition, in which the feldspar became altered into kaolinite and the augite into a rusty, non-transparent mass. In fresh condition the rock is dark, blackish green colored, and under the microscope the plagioclase is transparent, exhibiting polysynthetic striation; the augite is partially altered into a green substance. Next incumbent on the diorite rocks are hydromicaceous and feldspathic schists of light greenish yellow color with blood-red streaks and blotches tinged with hematite. Other streaky portions of these schists are lead-colored by an abundance of octahedric magnetite grains incorporated with the mass. These eminently schistose beds in part resembling novaculite, by segregation of flesh-red orthoclase crystals and of transparent quartz grains, by gradations merge with a massive protogine or granite which underlies these schistose strata.

Above this quite large belt, which dips under an angle of about 60 degrees to the southwest, succeeds a series of dark, purplish blue, ferruginous quartzite beds of metallic lustre, amounting in the aggregate to 400 or 500 feet. The color of the beds is due to their impregnation with specular ore granules, which in certain layers of the series amount to more than half of the weight of the rock, but all were too siliceous to pass for an ore salable in the present iron market.

Next above this large body of lean iron ore, as I may term it, follow light colored, slaty, silico-argillitic and hydromicaceous beds, which also amount to a wide belt; upwards in this succession calcareous seams begin to intermingle until heavy compact limestone beds of pale reddish color finally exclude all the slaty beds and terminate the exposures by forming a separate hill range, totally composed of limestone.

About a mile north of this locality, in Sec. 34, a similar but somewhat different group of iron-bearing beds is observable. The surface there is to a great extent covered with drift and Silurian sandstone. My observations, therefore, depended principally on an examination of a row of test-pits opened at right angles to the strike of the formation, which is there north and south, the dip west. Commencing on the east side, the first test-pits have uncovered red colored micaceous argillites in harder and softer slaty layers, in the next ones quartzite beds intersected with irregular seams of a steel-gray siliceous iron ore can be seen, then follow others dug into a belt of micaceous argillites, and next another large belt of quartzite of light color succeeds, then come quartzose hydromica-schists, partly dark blackish, partly light colored, which are interstratified with ledges of limestone. The beds are no further denuded.

A half mile northwest of this place, in Sec. 28, in the embankments of Michigamme River, and likewise lower down stream in Sec. 32, large exposures of a red colored, compact limestone interstratified with slaty seams occur; the limestone belt is several hundred feet in thickness. In the adjoining bluffs on the north side are seen denuded quartz-schists, banded with ore seams and slaty rock beds, their beds dipping in conformable steep inclination under the limestone.

From here northward unto the Republic mine I did not examine. From reports of explorers I learn that on this interval in many places the ore-bearing series forms the surface rock, but deposits of iron ore, being valuable, have not been discovered by them.

(C) GOGEBIC REGION.

It remains for me to report on another iron district which recently has attracted much attention of the mining and speculating public; this is the country environing Lake Gogebic.

The occurrence of iron-bearing rocks in the Gogebic country was first made known by the linear government surveyors, who indicated the localities on the town maps where iron ore was found by them. During the progress of the present geological survey Major Brooks and Professor Pumpelly went over that ground and gave a short description of the geological features of it in the first volume of the Michigan Geological Reports. Then scarcely any mining explorations for iron had been commenced there, but shortly after, the Gogebic iron range and its continuation, the Penokee range in Wisconsin, became the favorite resort of iron-hunters.

Since then a large amount of labor and capital has been and is yet spent there in explorations, partly with success, partly leading to disappointment, which is not otherwise to be expected.

The eastern portion of the range, extending from Lake Gogebic to the Montreal River across the center part of the ranges 44, 45, 46 and 47, of the town tier 47, did not prove to be much charged with iron ore to the east side of Sunday Lake (more recently, after I examined this region, also east of Sunday Lake, iron was discovered, but as it appears, not in paying quantities), but west of it unto Montreal River it was found to be richer and in a number of localities iron ore of very good quality and in paying quantities is so far demonstrated to be present, but no actual mine has been opened yet, as these remote places must first be brought into communication with the outside world by the construction of a railroad, which is surveyed but only partially built at this time.

My own observations in that district which I am going to describe depended in a great measure from the work of the explorers, as natural exposures are very limited in these unbroken forest lands, and many of those existing escape the attention of a transient traveler who usually cannot see many rods beyond the spot he stands on. On this occasion I also express my thanks for the many favors I received from these kind-hearted woodsmen while I was among them, and without whose help I could not have accomplished much.

Examining the general geological structure of the country surrounding Lake Gogebic, we find the entire circumference of the lake formed by sand beaches or terraces of boulder drift; the boulders are of large size and are in the great majority derived from the Keweenawan group, consisting of various modifications of red porphyry and of melaphyr and amygdaloid rocks; a smaller proportion is granitic-gneissoid and dioritic. Not a great distance off from the shore on the north side and the north half of the west side of the lake, the rock walls of the Keweenawan diabases begin to rise successively into hills from 200 to 500 feet in elevation.

The iron-bearing Huronian rock belt from the direction of its trend should be expected to strike the west side of the lake in its south half, but no outcrops of it are seen nearer to the lake than a mile or two from it.

Only at the extreme end of the lake, where a river enters it, bold bluffs of rock about 60 or 70 feet high rise directly from the edge of the water; they are hard schistose or slaty beds dipping under a steep angle southward; their composition is a minutely granular feldspathic groundmass in intimate intermixture with mica scales of great delicacy, which impart a silky lustre to the dark gray colored ledges.

This slaty rock is found to compose all the surrounding hills in the background and to form a belt several thousand feet in thickness. Following the river from the inlet upward, it has for two miles a very sluggish, meandering course, bordered by low marsh lands. At its junction with several tributary creeks, the ground rises and the hills come close up to the streams, which, in their narrow ravine-like valleys, have a swift current and in their descent over the denuded edges of the slate-rock formation on the steeper parts of the hills form numerous low cascades. The endless succession of slaty strata visible in the beds of these creeks varies some in grain, color and hardness, but the entire complex has one common general character in its structure and composition, by which the members belonging to this belt are, without difficulty, distinguished from other rock formations coming in contact with them in this vicinity.

I followed the principal branch of the river from its union with the other branches, in its narrow bed bordered by steep bluffs of the slate-rock, to the quarter-post on the south line of Sec. 16, then went on the section line as far as to the southwest corner of Sec. 14, returning diagonally across Sec. 15 to the S. W. ¼ of Sec. 9, where I had my camp.

With the exception of a belt of dioritic outcrops on the line between Secs. 14 and 15, all the surface rock I could see on this circuit walk belonged to the slate formation, and the dip of the strata regularly was directed southward. The Government surveyors have noted on the town maps the occurrence of a belt of iron ore near the center of Sec. 15, but my attempts to find this outcrop were not successful. The dioritic rock belt before mentioned is at the surface there in contact with the micaceous schists, but the ore seam I could not discover.

Wishing to examine the rock formations south of this area formed of slate-rock, I accepted the invitation of an explorer to accompany him to Sec. 35, T. 46, R. 43, where he pretended to have found a gold-bearing quartz vein intersecting the granite. The trail he led me went through almost impenetrable brushes of ground-hemlock (Taxus Canadensis) in alternation with spacious marsh grounds, where acrobatic dexterity was required to walk the slender poles laid across the bottomless mud holes; finally he showed me, in the midst of an alder bush swamp, a few knobs of granite associated with hornblende rock of laminated gneissoid structure, emerging only a few feet above the general level, which rocks were intersected by a narrow vein of milky quartz containing small, thinly scattered concretionary masses of iron and copper pyrites, so little promising in appearance that even in case the pyrites were auriferous, which I positively doubt, the poverty of the quartz vein in the pyritous minerals would preclude all expectations to mine with the slightest hope of success. After a short rest from this tiresome walk we took our back tracks, both disgusted, the explorer because I would not believe in the value of his discovery, and myself for having seen so little of the structure of the country over which I had to travel with so much exertion, as after we left the mica-schists exposed in the creek bed in Sec. 21, no more outcrops of any kind of rock could be seen along our path until we came to the aforesaid patches of granite.

A year afterwards I came again to the southward of Gogebic Lake, accompanied by Mr. P. Mitchell of Ontonagon, who, carefully searching for the ore belt noted on the maps of the surveyors, finally succeeded to find such a belt trending from east to west across the north part of Sec. 13, T. 46, R. 42, and was presently at work to test its value by sinking a row of pits transverse to the stratification.

The strata dip south under a high angle in conformity with the overlying mica-schist formation before described as being the prevailing surface rock in the surrounding country. In the pits an almost uninterrupted cross-section through about 800 feet of strata is laid open.

Farthest north a large body of partly massive, partly schistose dioritic rock projects in bluffs along the slope of the hills; conformably resting on these succeeds a series of dark lead-colored, silky, shining, fine-grained and very even-bedded slaty rock beds

of micaceo-feldspathic composition, about 100 feet in thickness; then follows a banded alternation of similar schistose material, with quartz seams amounting to nearly the double thickness of the former, which beds are in a considerably twisted corrugated condition. The thinly laminated alternating seams are from time to time interposed with large lenticular, flinty quartz masses and locally, instead of being corrugated, the rock seams are fractured and recemented into a breccia. South of this series lead-colored, even-bedded micaceous slate-rock layers similar to those lowest in the section, set in again in great force; they are copiously disseminated with magnetic granules as also the banded rock series below them locally was. Within these upper magnetite-bearing micaceous schists are interlaminated larger and smaller belts of banded magnetic ore, the bulk of which consists of about one half of its weight magnetite, the other half quartz grains and mica scales; the richer seams of the banded ore mass on analysis yield about 11.5 per cent of insoluble residue, 56.3 per cent of metallic iron, 5.7 per cent of carbonate of lime and magnesia, and an unusually large proportion of phosphoric acid, amounting to 1.38 per cent. South of the test-pits furnishing the siliceous ore, succeeds a large series of quartziferous actinolite-schists containing an abundance of octahedric crystals of magnetite; interstratified with them are dark green biotitic and chloritic schists which enclose locally a large number of garnet crystals, varying in size from that of a pea to that of a small hickory nut; also seams of magnetic ore are found within them. Then another succession of smooth-bedded, lead-colored mica-schists is met with by going south across the formation. Beyond them, after traversing a covered space, we find a dioritic rock belt similar to the one on the north side of the described section. All the surface rock south of this diorite belt is formed by the mica-schists which I have previously considered as analogous with the mica-schist formation of the Michigamme region.

The direct superposition of these mica-schists and the general lithological character of the strata enclosing the iron ore seams induce me to suggest their identity with the ore-banded actinolite formation overlying the magnetic ores of the Michigamme mine, and particularly with the ore-bearing series of rocks at the Magnetic mine.

The iron-bearing strata of the range extending from the center of the west side of Lake Gogebic towards Penokee Gap, differ in many respects from the just described group, but nevertheless I think to have sufficient reason to consider them as representative of the same geological horizon and as younger than the Marquette and Felch Mountain ore deposits.

The ore-bearing strata displayed in the Menominee region, on the north side of the Quinnesec ore range, are in all probability a perfect counterpart to them. Here as well as there a large belt of limestone forms the base of the series; the ore in both localities is, to a great extent, limonitic ore; in both places are graphitic schists associated with the ore deposits, and in the Penokee region the immediate succession of the mica-schist formation above the ore formation, is a further indication of the younger age of this group.

The following detailed description of the Gogebic iron range will enable the reader to judge for himself whether the proposed suggestion is admissible or not.

Starting from the landing on the west shore of Gogebic Lake, situated in the center of Sec. 17, T. 47, R. 42, on an old Indian trail, we meet for the first two miles no rock exposures, thence repeatedly in the hillsides, to the left of the path, bluffs of rock are seen to project which, on examination, are either granite or the brecciated diorite rock mentioned in the previous chapter; farther on, quartzite beds are seen to underlie the surface on the right hand side of the trail as we approach the mining camp of Mr. Gillis, situated in the southwest quarter of Sec. 14, T. 47, R. 43, where, by natural and artificial denudation, we are enabled to see a cross-section of about 800 or 900 feet of strata which dip under a high angle to the north. The aforesaid brecciated dioritic schists are seen in the hillside south of the camp, as the lowest; on them succeeds a belt of dark comglomerate, composed of quartz pebbles of various colors and of granite pebbles, cemented by an arenaceous groundmass holding a considerable amount of feldspar grains besides the quartz sand. Then follow thick-bedded gray quartzite layers; on them rests a flesh-red colored, compact granular quartz belt, which, by exposure, weathers and becomes porous, absorbent, like an ordinary sandstone.

Higher still are brecciated quartzite layers composed partly of chalcedonic quartz masses and intersected by irregular fissure seams filled with galena.

On this brecciated quartzite belt follow thinly laminated quartz layers of very uneven surface with interposed narrow wedgelike seams of black shaly material which causes rapid disintegration of this belt into shelly fragments. Within this series occur streaky interrupted concretionary seams, parallel with the stratification, which are filled with galena. Higher beds, likewise mainly of quartzose nature, are even-bedded, delicately striped or lineated in the direction of the bedding by the alternating intermixture of linear graphitic seams with the granular quartzose feldspathic groundmass, which besides holds a good proportion of the carbonates of lime and of iron; weathered surfaces of the white and black striped rock are therefore rusty brown. In some of these layers the shaly graphitic material predominates over the quartzose, which causes them to be softer, more pliable; the upheaving pressure therefore folded them throughout their substance into innumerable small wrinkles, as we often observe the same phenomenon of corrugation in the still softer sericitic or micaceous schists in other geological horizons. North of these beds follow uniformly black, fine-grained, slate-rock layers, which are from time to time interlaminated with seams of harder siliceous ledges likewise black colored by carbon; the aggregate thickness of this uppermost graphitic slate-rock belt amounts to about 500 or 600 feet. It comes, on the north side, in direct contact with the diabases of the copper-bearing rock group, which appear to be conformably superimposed on it.

The galena, according to several samples analyzed by me, contains only a small proportion of silver, too little to work the mine for its value in silver, and for the lead alone, I think, the supply of ore obtainable would be too small.

This galena-bearing quartz formation and the graphitic slate series above it are traceable by extensive exposures in the hillside along the trail, until it crosses Presque Isle River in the S. E. ¼ of Sec. 17, the bed of which is carved there diagonally across the stratification into the black graphitic slates, amounting also there to a very thick succession of beds.

A mile farther west, in the S. E. ¼ of Sec. 18, T. 47, R. 43, I met, for the first time, with outcrops of dark purple colored, banded quartzite beds formed of alternating seams, some of them richly impregnated with specular ore grains, and others of a more purely quartzose composition; the rock belt to which these strata belong, is exposed in the bed of a small creek, but the exposures are too limited to offer a cross-section giving information of the thickness of this belt and of the rock adjoining it, but as the trend and dip of the beds are in conformity with the graphite-slates and the galena-bearing quartzites, it is probable that they belong approximately to the same geological horizon. West of this creek, the trail follows the south line of Sec. 18, and then of 13 and 14 in the adjoining township, into Little Presque Isle River, a side-arm of the other. The ferruginous quartzites trend westward some distance north of the trail, which passes over dioritic rocks for all this distance.

I have in the previous chapter mentioned the generally fine-grained quality and light color of these rocks, and the occurrence of schistose brecciated belts in association with the massive. High bluffs of these breccias border the east side of Little Presque Isle River, from the top of which the rare opportunity of an extensive panoramic view to the west and south offers itself, which, after many days confinement within dense forests, restricting one's vision to the distance of a few rods, is a great relief, wonderfully invigorating the spirits suppressed by the former monotony and the connected fatigue of the travel.

West of Little Presque Isle River, which here coils its flow into the most intricate curvatures, very perplexing for a stranger not informed where to cross the marshy valley, densely covered with willows and alder bushes for several miles; no rock exposures are visible alongside the trail. Approaching the southeast corner of Sec. 17, T. 47, R. 44, compact light colored quartzite beds form the surface rock and project sometimes in a row of bluffs; further proceeding, we find on the left side of the trail, across the south part of Sec. 17, a rocky hill range of considerable elevation trending westward, which is composed of a large succession of siliceous limestone beds, dipping under a steep angle northwest. South of the limestone, dark colored schistose quartz-rocks of granular structure with an interstitial hydromicaceous and partly chloritic cement, are the underlying rock beds. The structure of the limestones with interlaminated siliceous seams and the corrugations of the beds correspond entirely with the limestones connected with the ore-bearing beds of the Menominee district. On the west line of Sec. 17, the trail we followed turns northward, diagonally across Sec. 18, and thence leads

through the north half of Sec. 13, T. 47, R. 45, to the southeast corner of Sec. 11, where Mr. Gillis had erected another exploring camp. All the exposures we met with on this path were quartz-rocks, whitish or reddish colored, and at times some slaty rock-layers were found, interlaminated with the quartz beds.

Near the camp are good natural exposures, and the test-pits of the explorers had pretty thoroughly uncovered the beds in the intervening spaces, so that quite a large series of rocks could be observed here in an uninterrupted cross-section by correlation of the different openings.

Commencing the examination near the southeast corner of Sec. 11, we observe the following succession of beds: At the base of the south slope of the hill range on which the corner is located we find thick-bedded, compact, light colored quartzites dipping under a steep angle to the north; above them conformably follows a series of brecciated quartzrock beds, consisting of a well laminated fine-grained, somewhat porous cherty groundmass, more or less impregnated with hydromicaceous scales, drab colored and blotched with irregular red spots, which encloses numerous angular quartz fragments, some with glassy fracture, others of the nature of a brownish chalcedony; the thickness of the brecciated belt amounts to about 30 or 40 feet.

It is succeeded, upward, by a very large alternation of thin-bedded siliceous flagstones, with slaty layers changing in all shades of colors, gray, brown, red, greenish, and all with some degree of sericitic lustre.

The summit part of the hill range and all its north side are formed by these beds, amounting to an aggregate thickness of from 400 to 500 feet. Further north the exposures are for some distance interrupted by the swampy bed of a creek, but on its north side the strata are again uncovered by the exploring pits, after removal of about 12 or 15 feet of drift from their surface. They consist of a large succession of well laminated, very even-bedded, almost black colored fine-grained siliceous schists banded by the alternation of seams more richly impregnated with magnetic ore granules than the intervening ones. The black color appears to be in part due to graphitic or carbonaceous material, intimately mingled with the rock substance, and not to depend exclusively from the magnetite incorporated with it. Seams purely composed of magnetic ore are not found. This belt of magnetic schists is 1,200 feet north of the section line from which we started in the examination of this locality; it has a thickness of several hundred feet and is seen on the higher part of the hill slope in close contact with an overlying diabase belt of the cupriferous formation, which, farther north, other partly amygdaloidal, partly porphyritic diabase belts follow.

The contact of the magnetic schists with the diabase belt is to all appearances conformable. A mile west of this place are numerous other exploring pits opened, a part in the N. W. ¼ of the S. W. ¼ of Sec. 10, another in the N. E. ¼ of the S. E. ¼ of Sec. 9.

There was discerned a succession of about 500 feet of red colored banded jaspery beds, with likewise red colored slaty seams interstratified, which softer slaty beds locally were so rich in hematite iron oxide, as to be with difficulty distinguishable from the hematitic ore deposits, of which lenticular seams, widening at times into larger pockets, were found in the same association of rock beds; besides these soft paintlike hematite ores, occur also pockets of a harder, compact hematite ore.

Some of these ore deposits promise to be large enough to have value for the miner. A difficulty in mining them would be to prevent the mixture of the ore with the surrounding shattered, brittle, siliceous rock beds, scarcely differing in color from the ore.

An analysis of the soft kind of hematite showed in one specimen 91.4 per cent oxide, 6.66 insoluble residue; another held only 70 per cent of the oxide and 27.2 per cent of insoluble residue of argillaceous nature. The amount of phosphorus in both specimens is small.

This series of red colored hematitic rocks is, on the north side, in direct contiguity with diabases of the Copper-bearing formation. No equivalent of the magnetic schist forming the contact line in the other locality is noticeable here, but south of the test-pits, after passing over a covered space about 300 or 400 feet wide, we find the continuation of the hill range from which in the former place we started in the description of a cross-section. Most likely therefore the dark colored magnetic schists would be found in this covered interval between the hematite pits and said hills.

In this locality a great difference in the angle of inclination of the strata is observable; the beds closest to the diabase stand

almost vertical, while those in the test-pits farthest south have a dip of only thirty or forty degrees to the north.

Not a great ways west of the test-pits we find Sunday Lake, on the other end of which we come to other exploring pits for iron, in Sec. 7, T. 47, R. 45. On the maps of the Government surveyors a row of hills crossing the south part of this section is marked as consisting of iron ore, which is in reality a large belt of the magnetic schists analogous with those found in the test-pits in Sec. 11, as before described.

These dark, blackish colored, slaty rocks, interlaminated with belts of compact quartzite, like the slate impregnated with magnetic granules, amount to 400 or 500 feet in thickness; their dip is north, under a high angle, and on the north side they are conformably succeeded by an equally large succession of red colored, jaspery beds in banded alternation with seams of more or less siliceous red oxide, just the same series as we found in the pits on the east side of Sunday Lake. The upper horizons of this group of beds are much richer in iron ore than the lower, but so far no profitably workable deposits have been discovered in this locality. We find here again the copper traps in conformable contact with the ore-bearing series.

While unto here all the explorations for iron promised to be most successful in the upper horizons of the formation, above the belt of dark magnetic schists the exploring work farther west is principally confined to the lower part of the series beneath the magnetic schists.

The exploring pits found in that direction are therefore situated about one mile south of the South Trap Range, following the northern slope of a granite range which trends parallel with the northern trap ranges.

The first of these exploring pits we meet with are in the S. W. ¼ of the N. W. ¼ of Sec. 13, T. 47, R. 46. In close contact with the granite, which forms there the summit part of the hills, we find a light colored, porous, gritty, silico-argillitic rock in rather compact masses, showing little of bedding. Above it follows a great succession of alternating beds of quartzite and slaty or shaly seams, which are all more or less impregnated with brown or also red oxide of iron, and besides inclose irregular seams and pockets of clean ore substance.

Of the quartz beds, some are light colored and thick, but the majority are thin or flaggy, or form a banded alternation of dark colored, ferruginous and of lighter, purely quartzose seams, which ferruginous bands, parallel with the formation, are connected by cross-fissures filled with limonitic ore, which crevices expand sometimes into larger pockets. This proves the secondary infiltration of the greater portion of the iron oxide. In connection with the dark, red colored, slaty beds occur seams of soft, blood-red hematite. The harder ore filling the crevices between the quartzite layers is dark purplish brown colored, of fine-grained, dull, earthy fracture, but part of it has the radiated crystalline structure of the so called grape ore, and also non-hydrated red oxide is mingled with the ore masses, which gives them a purplish hue. From here to the west end of the state an uninterrupted chain of granite hills extends and continues into Wisconsin after crossing Montreal River.

Everywhere on the north side of this range the iron-bearing rock group is found. The prospects for large bodies of ore are not very favorable in Sec. 13; much better is the show in the test-pits opened in Secs. 15 and 16, under the supervision of Capt. Moore of Ashland, and of Capt. Pease of the same city. Their pits are opened below the edge of the plateau-like hilltops from which, a number of years ago, by a tornado, all the timber was blown down and subsequently was destroyed by fire. At these localities, therefore, a splendid free view is opened in all directions, and particularly northward unto Lake Superior.

The ore deposits here are secondary accumulations in the crevices of a quartzite formation, interlaminated with slaty argillitic rock beds, the total thickness of which series is near a thousand feet. The lower portion of this rock series consists of light colored, slaty beds, which repose on diorite or granite. Next above them, thick, massive, light colored quartzite ledges follow in great force, then a more thinly laminated series of quartz beds succeed, alternately interstratified with slaty argillites. Most of these beds are intensely red or reddish brown colored, or lighter and darker colored seams follow in regular alternation; sometimes a belt of argillites is also fancifully speckled with white and red dots. Within this series, in three or four different horizons, seams of hard, partly limonitic, partly non-hydrated iron oxide have been discovered, which locally change from the width of three and four feet to that of eighteen and twenty. The great bulk of

this ore is an almost aphanitic, fine-grained, compact, bluish, dark colored mass with smooth, conchoidal fracture, giving a purplish brown powder, as it consists of a mixture of hydrated and non-hydrated oxide. The aphanitic substance is permeated with an abundance of radiated concretions of grape ore, giving a powder of light yellowish brown color, but a part of such radiated crystalline concretions consists also of regular hematite, giving a bright red powder, and in the same form also pyrolusite is a very common associate of the iron ore. Where druse cavities exist the grape ore and the pyrolusite often occur in stalactitic form. On the west side of Mr. Moore's explorations, Mr. Pease opened in the N. E. ¼ of Sec. 16 a row of trenches 700 feet long, within the upper thinly laminated banded beds of the series, and laid bare a belt of crumby, partly limonitic, partly hematitic ores, enclosing numerous nodular concretions of pyrolusite, which averages 22 feet in width.

An analysis of a piece of the compact aphanitic ore from Mr. Moore's test pits, gave the following result:

Loss by ignition,	5.2	per cent water.
Insoluble residue,	2.9	per cent.
Oxide of iron,	91.9	" "
Phosphoric acid, small amount, not weighed.		

Another specimen of blackish steel-color, with flinty fracture, gave

Water,	2.5	per cent.
Insoluble residue,	1.36	" "
Oxide of iron,	74.	" "
Manganic oxide,	16.7	" "
Phosphoric acid, small quantity, not weighed.		

A specimen of compact ore, mingled with grape ore bunches, gave

Water,	6.16	per cent.
Insoluble residue,	1.8	" "
Oxide of iron,	90.	" "

The soft, crumby ore from Mr. Pease's mine gave

Siliceous residue,	2.	per cent.
Oxide of iron,	94.	" "
Oxide of manganese,	2.	" "
Phosphoric acid, small quantity.		

Explorations in the same complex of rock beds were in progress farther west, in Secs. 17 and 18, all having the success of meeting with similar ore deposits, some of them promising to be of value.

In the next western township, N. E. ¼, Sec. 24, T. 47, R. 47, I passed exploring pits in which a belt of dark colored, blackish, soft, crumby ore, about four feet wide was laid open, which enclosed a large quantity of concretions of pyrolusite in radiated bunches of brightly shining prisms. Heavy, light colored quartzite beds form the foot wall of this ore seam, and beneath them a large succession of light colored, siliceous, argillitic slate-rocks is exposed. North of the ore seam red colored, banded jaspery layers are exposed in association with very even ferruginous beds, of metallic luster by rich impregnation with specular ore granules. These are fissile into thin, large slabs, which have been put into use by some of the explorers to cover their huts, for which purpose they answer admirably well. On the north side of these flagstones, a large succession of black graphitic slates follow conformably in this and other localities farther west. On Michigan territory, the last exploring pits for iron are found close to the S. E. ¼ of Sec. 22; the work is superintended by Mr. Wood. The work in that place, at the time of my visit, had not far advanced, but from all I could observe, the strata containing iron ore seams were about the same as in the previously examined localities. Bluffs of granite projected on the south side of the test-pits, no farther off than sixty feet. In the bed of Montreal River, next above the mining camp, a singular, dark colored belt of a breccia crosses the river, which consists of angular, flinty quartz fragments, embedded within a crystalline groundmass formed of carbonate of lime, iron and magnesia; weathered portions of the rock were transformed into a soft, ochreous brown substance, or also having the red color of hematite. On the north side of this quite broad belt ferruginous quartzite beds were exposed, corresponding in appearance with the ordinary layers making part of the iron-bearing series. On the south side, the breccia came in contact with a large belt of diabase, and further south the granite was surface rock. The diabase accurately resembles the diabase rock intersecting in dykes the rocks in the vicinity of Marquette, as for instance, the diabase belt on which the Marquette lighthouse is erected. Under the microscope, its components are transparent prisms of plagioclase and pale brownish augite crystals in about equal proportions, with the addition of a good number of scattered groups of transparent, almost colorless olivine grains intersected by a network of

seams in which minute magnetic granules are crowded together. The circumference of the clusters of olivine grains is also usually dark green colored by infiltration of viridite.

(D) PENOKEE-GOGEBIC REGION, WISCONSIN.

From the Montreal River I followed the iron-bearing rock belt into Wisconsin, which was the shortest way to get out of the woods and more instructive than my return by the same way I came would have been. Crossing Gogogashung River at the south end of an island the river incloses, I had an excellent opportunty to see a very large succession of beds representing the lower horizons of the iron-bearing rock series, as the river had carved its channels across this group of beds. It rushes over them in rapids and a number of smaller cascades, in both of the arms enclosing the island, while above the island a large body of underlying schistose dioritic rocks form the bed of the river. The schists above the diorite form well laminated, even and compact beds of slatelike fissility; their colors are rather light, varying in all shades from gray to greenish, bluish, reddish, brownish; they consist of a fine-grained, silico-feldspathic mass, charged with a greater or smaller proportion of minute mica scales; from time to time coarser arenaceous seams mingle in between the fine-grained, slaty laminæ. The aggregate thickness of this belt amounts to about 300 feet; the dip of the strata is north, under an angle of about fifty degrees. Reposing on them is a series of quartzite beds partly in thick layers, but most of them thin, flaggy and in alternation with softer argillitic seams. All these beds are more or less impregnated with oxide of iron, either merely as a pigment or also as larger concretionary seams of iron ore, limonitic or hematitic. These ore accumulations occur principally in a part of the belt in which the ledges are found shattered into small, angular fragments, and recemented into breccia by these infiltrated ore masses, which, however, accumulated also in the not so much shattered portion of the quartzrock series. What succeeds north of this belt I have not examined, as an accurate geological description of the environs of this place is given in the reports of the Wisconsin Geological Survey.

Two miles farther west, in the north half of Sec. 33, T. 46, R. 2 E., Wisconsin, explorers have opened a large number of test-pits and longer trenches across the stratification. In these we see farthest south, next to granite bluffs, the same light colored slate-rock series which forms the river bed of Gogogashung River, in the circumference of the island. Above the slates, thick-bedded, light colored quartzite layers and then more thinly laminated, jaspery beds of reddish or brownish color follow. Within this rather wide belt of quartzose beds, irregular seams of iron ore, parallel to the stratification and in transverse seams and pockets, have been laid open, of which some promise to be valuable. This ore is a compact, fine-grained, aphanitic mass of purplish black color, with a smooth, flinty fracture, and in association with it concretions of grape ore are of frequent occurrence.

An analysis of the aphanitic compact ore in one sample gave

Iron oxide,	90.	per cent.
Quartzose residue,	5.	" "
Water,	1.4	" "

Another specimen analyzed gave

Iron oxide,	93.8	per cent.
Siliceous residue,	4.34	" "
Loss by ignition,	1.106	" "

The amount of phosphoric acid in both samples was not great.

North of this group of ore-bearing quartzite strata a broad belt is formed of red colored, banded, jaspery beds in alternation with likewise intensely red colored, slaty argillites, which strata locally also inclose seams of soft hematite ore, some of them three or four feet in width. Next above this group follows a belt of the previously described dark colored, ferrugineo-siliceous banded layers, with bright metallic lustre on the bedding planes, which can be split into thin, even slabs of several feet square and not over half an inch thick; they emit a loud, ringing sound under the stroke of a hammer. Thence farther to the north, a large succession of black graphitic slate-rocks can be traced, until the rock exposures disappear altogether in marshy lowlands, beyond which, at no great distance, the trappean hills are seen to rise.

From here to Penokee Gap, a distance of twenty miles, I had to travel in a constant pouring rain, which prevented me from closer examination of this strip of land, which, by its extensive rock exposures and the regularity of their disposition, is the

most interesting of all that I had seen on the entire range from Gogebic Lake.

The path led me along high rock walls of light colored limestone ledges and quartzite beds, dipping in steep inclination northward, which were succeeded on the north side by a broad belt of light colored silico-feldspathic slate-rocks, on which rested conformably a considerably thick series of dark colored, banded ferruginous rock beds, with bright metallic lustre on the bedding planes, which were formed of an alternation of thin, even seams, almost totally composed of specular ore granules, with others, in which quartz grains, red-tinged by hematitic pigment, prevailed much over the grains of ore in the mixture. In this belt, most tempting by its appearance as a repository of larger masses of pure ore, as I passed along it I found the explorers had spent a great amount of time and labor, but their efforts seemed to be nowhere rewarded, as the large excavations made by them were all abandoned, and no appreciable quantity of high-graded ore masses could be seen amongst the large burrows of rock thrown out of the drifts and shafts, which rock, taken in its totality as the belt furnishes it, contains almost half of its weight in granular martite. A most complete natural section across the iron-bearing rock series, from the granite at its base up to the top part of the Huronian series, and continued across the overlying porphyritic and diabasic rock belts of the Copper-bearing formation, is presented by the channel of Bad River, at and north of Penokee Gap, which cross-section is described in detail by the geological reports of Wisconsin, to which I refer the reader. Comparing this section with the succession of beds on the east side of Montreal River, a general correspondence is observable, but also considerable local differences in the development of the strata are obvious. The limestone belt forming at the Gap the lowest member of the formation and composing rock walls conspicuous all along to the vicinity of Montreal River almost disappears on its east side in Michigan; only in the south part of Sec. 17, T. 47, R. 44, a larger body of the very siliceous limestone ledges shows itself at the surface. The next succeeding rock belt, composed of light colored silico-feldspathic slates, is traceable to the east side of Sunday Lake. The ore-bearing beds are at the Gap represented by dark colored magnetic actinolite-schists. Of the red hematite-bearing jaspery rock series and of the underlying quartzrock beds intersected by seams of compact limonitic and hematitic ore, which in more eastern localities occupy a place next above the before mentioned light colored schists, nothing is exposed at the Gap; the even-bedded, banded, specular, lean ore belt of metallic lustre, which follows the east side of Montreal River on the north side of the jaspery hematitic series, is here the only representative of this horizon near the Gap. North of it follows a very large succession of dark, blackish colored slate-rocks, interlaminated with brittle, flinty, siliceous rock masses and locally intersected by dioritic belts which seem to be intrusive, which dark slate-rock series is everywhere traceable as far as Lake Gogebic, constituting the upper horizon of the iron-bearing series.

The large belt of magnetic schists in the vicinity of Sunday Lake seems to be its analogon, but anomalous is the occurrence of a large succession of jasper and slate beds, impregnated with hematitic oxide and carrying deposits of hematite ore, on the north side of this belt, as we find it near Sunday Lake. It is therefore possible these dark magnetite-bearing schists might not be the equivalent of the black slates on top of the formation near the Gap and near the Montreal River; but the equivalency of the latter with the large belt of graphitic slates intersected by the Presque Isle River, and east of it, near Mr. McGillis's test-pits for galena, appears to be unquestionable.

(E) VERMILLION RANGE, MINNESOTA.

While engaged on the frontiers of the State, I received an invitation to visit the lately opened iron mines on Vermillion Lake, in Minnesota, which I gladly accepted, as the ore deposits of that region were reported to exceed in size and quality any of the other ore deposits of the Lake Superior district, and to occur in a series of rocks analogous with those associated with the ore in the Marquette region.

A railroad sixty-seven miles long, built from Agate Harbor to the mines, brought me there within a few hours, which travel to the mine, a while before, could scarcely be accomplished in a week under great exertions.

The hills on which the mines are located border the south shore of the eastern part of Lake Vermillion; their trend is from southwest to northeast; their elevation above the surrounding country

is not over 200 feet, and the level of the railroad track at the mines is 800 feet above Lake Superior. The strata composing the hills stand almost vertical; their dip is generally northward, where it can be determined.

Commencing the examination of the rock series on the south side of the mining location, we meet first with a wide belt of light colored gray or greenish or bluish colored hydromica-schists, with interlaminated quartzose seams. Some layers of the schists have a bright satin lustre; in others the lustre is only faint. In the aggregate, the visible portion of this belt amounts to 400 or 500 feet; its north side joins a belt of iron ore from ten to fifteen feet in width. The ore is compact, fine-grained, almost aphanitic, with smooth, conchoidal fracture, of dark purplish, steel-gray color. Occasionally granular-crystalline or radiated-fibrous, concretionary portions are intermingled with the compact masses. On the north side this ore seam is succeeded by other hydromica-schists, more argillitic than the former, some layers intensely red colored or variegated by alternation of irregular whitish and red blotches, much resembling the so called soapstone of the Negaunee mines.

North of this comes another belt of compact ore, much larger than the former but resembling it in quality. In places, the width of this ore belt is sixty feet, and rarely it shrinks down to less than thirty feet, in the trenches by which this belt is laid open for the length of nearly a mile. Its north side is joined by a belt of jasper-banded mixed ore, a regular fac simile of the red, jasper-banded, lean ore belts in the mines of Negaunee and Ishpeming; like there, also here, these banded layers are locally bent and twisted into zigzag plications. Between the regular alternation of thin red or purplish colored jasper seams, with equally thin seams of compact ore, more or less siliceous are, from time to time, bulkier, lenticular masses of clean ore wedge-wise. North of this mixed ore belt follow again hydromica-schists of light color, more compact than the former, a granular ground-mass of feldspar composition intermingled with glassy quartz grains prevailing in them over the hydromica. The greater portion of this large rock belt is twisted into corrugations, or often also it represents a breccia of small fragments of the rock recemented by the same hydromicaceo-feldspathic material.

Past this large belt, red jasper-banded mixed ore appears in a second belt much wider than the first. It exhibits the same corrugation of its layers, and on its line of contact with the hydromica-schists on the south side both kinds of rock are interlocked by long spurs and loops projecting from one belt far into the other, in proof of the high degree of plasticity of both of these very different rock masses at the time they became interlocked. On the north side of this jasper-banded mixed ore belt, we find the same kind of hydromicaceo-feldspathic schistose rock succeeding it, which joins its south side; also this belt has a much shattered brecciated structure and considerable width. Next in the succession, a wide belt of banded magnetic quartz-schists follows, the structure of which is very similar to the red jasper-banded rock belts before met with, but the quartzose seams of this rock are dark brown, also blackish colored, and the intermediate ore seams and oxide granules disseminated through the whole mass are not, as in the former rock belt, martite or sesqui-oxide, but consist of magnetite. The amount of magnetic ore contained in this belt is quite large, but not concentrated into seams large enough to be properly mined. Several abandoned shafts which I encountered witness a great amount of labor unsuccessfully bestowed on such localities. This region is at present overrun with exploring parties, most of which, relying on the dip needle as a guide in their explorations, principally stuck to one of these belts of magnetic schists and found themselves disappointed, instead of hunting for the large martite ore masses near by, which exert much less influence on the needle than the other, and have therefore to be traced by outcrops, and by learning their relative position with regard to the magnetic schists in a given locality.

Proceeding north across this wide magnetic schist belt, we come once more to a belt of schistose hydromicaceous beds interstratified with light colored quartzite belts, which series of rock beds continues down to the shore of Lake Vermillion, which is dotted with a great number of larger and smaller islands.

Standing at the shore near the quarter-post on the north line of Sec. 27, T. 62, R. 15, on outcrops of a white granular quartzite with an abundant sparry calcareous cement, we observe some distance farther north, on a projection of the land into the lake, a ridge about 50 feet high, trending parallel with the hills on our side, which is formed of another succession of magnetic

schists, the same in quality as the former belt, and on a large island farther to the north, the white cliffs bordering its shore are from the distance recognizable as a repeated outcrop of a belt of quartzite beds and hydromica-schists, which fact is ascertained to me by persons who have been on the island.

This cross-section from the mines to the shore of the lake and out into its islands, in all probability represents not one continuous succession of superimposed rock beds, but a repetition of beds by existing plications, which to demonstrate positively, a cursory examination like this was insufficient.

Southwest of the hill just described, on the north side of the village of Tower, this same rock series with interstratified belts of iron ore is displayed in another range parallel with the former. Farther south, about a mile from the mines, on the side of the railroad, I noticed large exposures of the light colored quartzites mingled with hydromicaceous schists, which beds, according to the descriptions of woodsmen familiar with this part of the country, form the surface rock over wide spaces. They seem to be the highest strata, through which deeper seated ferruginous strata came to protrude by means of great plications of the surface crust and subsequent erosion. Four miles south of the mine, near the engineer's camp, the railroad cuts through a large series of compact blue colored slate-rocks dipping north under high angle; between the fifth and ninth mile south of the mine, are other cuts through bluish colored quartz-schists, some of which beds are crowded with silvery shining mica scales; these beds have great resemblance to certain layers of the staurolitiferous mica-schist formation near Michigamme Lake. About twelve miles south of the mine we reach the base of Mesaba Heights, which consist of eruptive granite masses, well exposed naturally and in cross-cuts made by the railroad. After crossing the heights on their south side the entire group of beds, magnetic schists, hydromica-schists, hematitic ore belts, etc., occur again, succeeded further south by blue slate-rocks like those near the engineer's camp. These beds, flanking the south side of Mesaba Heights, are identical with those on its north side and on Vermillion Lake, but while the latter are found in nearly upright position and much distorted, these are gently dislocated and dip under comparatively low angles southeastward.

A few miles further south, about forty-six miles from Agate

Bay, the roadbed makes a cut through hillocks of coarsely crystalline olivine-bearing gabbros and for four or five miles, further on, these gabbros are again repeatedly intersected by the roadbed. This gabbro belt can be traced in continuous exposures southwestward to the city of Duluth, where in the south part large bluffs of it project and are quarried for building purposes, for which they are admirably adapted, as they are very durable and take a fine polish if used for ornamental masonry.

From this gabbro belt, which disappears under drift masses about forty miles off from Agate Bay, no more rock exposures can be observed aside of the railroad line, until about two miles this side of the harbor, where the diabases of the Copper-bearing rock group begin to show themselves at the surface and do so all the way down to the shore. The strike and dip of the entire rock series from Mesaba Heights to the shore of Lake Superior appears to be in perfect conformity.

The blue slate-rocks intermediate between the iron-bearing rock belt and the gabbro belt on the south side of Mesaba Heights and also found above the ore-bearing beds of Vermillion Lake, four miles south of the mines, are vastly denuded in the bed of St. Louis River, between Thompson and Fond du Lac.

Considering their position above the ore formation of Vermillion Lake, which in its entire complex has so much resemblance with the ore-bearing rock group of the Marquette district, that I identify them without hesitation, and comparing the slate formation with the equally large succession of slate-rock beds in the environs of L'Anse Bay and Huron Bay, which likewise occupy a horizon high up in the Huronian series, I find so complete a similarity between them, that their analogy is not to be doubted. Noteworthy is the frequent intersection of these slate-rocks by diabase dykes on St. Louis River and near L'Anse, and on the other hand the scarcity of such dykes in the lower beds of Vermillion Lake district, where none came under my observation during the short time I had for their examination. It was likewise unexpected to me to find in connection with the granites of Mesaba Heights, no diorite rock belts in the exposures on the railroad.

CHAPTER V.

ARENACEOUS SLATE GROUP.

The large succession of rock beds comprehended under this name in my preceding report, is represented as varying considerably in its lithological character in different localities of the small area of the Marquette region. Extending my observations over the western part of the Upper Peninsula, where corresponding beds are widely spread as surface rocks, I found them to differ greatly from those already described, still, considered in its totality, the group there is also mainly composed of arenaceous and slaty rock beds.

I could not avoid to enter several times into a description of rocks belonging to this horizon, in the previous chapter, as they occurred in close association of other older rocks, which separately to describe would have been inexpedient.

This group is of high economical interest, as it encloses immense stores of iron ore, which were partially known to the miners for a good while, but their relative position in the Huronian series has only recently become more clearly known.

During the past five or six years the attention of explorers for iron ore has directed itself earnestly to this geological horizon and within that short interval a great number of ore deposits of surprising magnitude have been discovered almost everywhere, as far as the formation extends. The principal masses of ore are found in a hydrated condition, but specular hematite and magnetic ores are not altogether excluded.

In a foot note of the previous report, on page 130, I mentioned as belonging to this group the ore deposits of the Taylor mine, in the vicinity of L'Anse, of the S. C. Smith mine, now called Cheshire mine, southeast of the Cascade mines, and of the Northampton and Dalliba mines, north of the Champion mine, to which at present a number of other localities could be added.

As I did not describe any of them, I let here follow a description of some of them.

The Taylor mine, one of the older mines worked in the district, but at present abandoned again, is located on the summit plateau of the granite stock intervening between Lake Michigamme and the Bay of L'Anse, the mining property being in the N. E. ¼ of the N. W. ¼, Sec. 9, T. 49, R. 33. Following a sidetrack from the Houghton & Ontonagon R. R. to the mine, we find the surface for almost the whole distance covered with drift deposits. The first rock exposures encountered are about 500 or 600 steps from the mine; they consist of graphitic slates, which dip under a high angle to the south; their visible thickness is about 200 feet. The outcrops are then interrupted by a swampy depression, on the other side of which succeed banded jaspery strata, composed of alternating narrow seams of whitish or brown colored flinty quartz and similar seams composed of compact dark brown limonitic ore, partly also of a mixture of limonitic with specular ore, which gives the seams a metallic lustre. Abundantly associated with these ore bands are also concretionary masses of pyrolusite in brightly shining radiated crystal clusters, by which fissures and druse cavities in the rock are sometimes totally replenished.

Having passed across about 250 feet of this belt, we see its ledges bent into an anticlinal arch, in which the anticlinal portions are pressed into parallelism with the former succession; the whole series of beds therefore dips south, the beds in the center of the arch being nearly vertical. Advancing farther on the road, which makes a deep cut into these beds, another similar fold occurs, then a diabase belt, sixty feet wide, diagonally intersecting the ledges, is met with. On the south side of the diabase belt graphitic schists are in contact with it, which dip south like the former series. The width of this belt is considerable. Past it succeed again the banded jaspery layers, in alternation with ore seams identical in appearance with those on the north side of the diabase belt. Next to them, southward, follow softer shaly or slaty argillites with from time to time interlaminated quartzite beds in a wide belt, which is more or less deeply red tinged by impregnation with hematite oxide. It encloses seams of a soft crumby iron ore of partly limonitic, partly hematitic condition, which seams locally widen into

pockets thirty feet in diameter, and much longer in the direction of the bedding. On the other side of the belt we meet again with the banded jaspery rocks and with graphite-schists on their south side. The so far described cross-section embraces the space from the north line of the section to its center.

Proceeding farther in this direction are seen repeated outcrops of graphitic schists, of heavy quartz layers of light color, intersected by fissure seams filled with limonitic ore, which widen sometimes into pockets; and again, of the ore-banded jaspery series with temporary interruption of the exposures by drift-covered spaces.

Approaching the south line of the section, a round ridge of diabase, trending from east to west, stretches across our way; it is a rock identical in appearance with the diabasic dyke rock above mentioned.

On the south line of the section, eighty rods west of the eastern section corner, graphite-schists, dipping under high angle south, are well exposed in test-pits. Other test-pits are 200 feet farther west, in which the ore-banded jaspery strata are exposed; near the quarter-post these jaspery layers are interstratified with intensely red colored, slaty argillites, which sometimes are replaced by deposits of soft hematite ore intermingled with limonite, widening into pockets. The explorations at the time had not far enough advanced to ascertain the extent and value of these deposits. The strata repose in steep inclination on the south slope of the hills, directly underlain by the before mentioned diabase belt and overlain by compact, but well laminated hydromica-schists consisting of a mixture of coarse opalescent quartz grains and fragments of red feldspar crystals, embedded within a groundmass of silky shining hydromica with chlorite. These beds, forming the surface of the slope of the hill down to the bed of Plumbago Creek, are succeeded on the other side of the stream by similar schistose beds much richer in red feldspar and containing only little quartz, which could be, on superficial examination, mistaken for granite, but are evidently a fragmental rock, formed of the detritus of the granite, which, near by, forms large mountain masses. The granite of these mountains is very rich in red feldspar and contains, comparatively, not much quartz; it also has a more or less distinct, seamy, laminated structure, and being in close contact with these schists, it requires great care to make proper distinction between the two, in origin, widely different rocks.

A half mile south, in the center of Sec. 16, after having crossed a granite hill, we find on the south side of another creek, tributary to Sturgeon River, a number of old exploring pits for iron ore. The summit part of this hillside is formed of similar quartz-bearing hydromica-schists as those near Plumbago Creek; some of the layers are much finer-grained, with no quartz grains in them. Beneath them follows conformably a large series of banded ferruginous quartzite layers, inclosing irregular seams and pockets of limonitic iron ore, but an exploring tunnel driven into these beds for quite a distance, does not show the intersection of any such ore seams which would be worth mining.

The base of this hillslope is formed of granite, but the talus, surrounding the projecting rock walls of the iron-bearing strata, covers up their contact line with the granite. On returning from here, I came to Plumbago Creek, a half mile below my first crossing place. Ascending the slope on its north side, I could observe, some distance above the sole of the valley, graphitic slates and associated banded ferruginous jasper strata, reposing discordantly on the granite, with steep inclination to the south. Higher up the slope the same beds are in discordant contact with the prolongation of the mentioned diabase belt, running along with the south line of Sec. 9, and forming vertical cliffs at the edge of the summit of the hill. Following from here the west line of Sec. 9 northward, I found, near the quarter-post, extensive exposures of hydromicaceous quartz-schists of silvery lustre. Beneath them, conformably dipping to the south, follows a large belt of banded ore-bearing quartzites, then comes a belt of graphitic slates, then again a wide belt of the banded ferruginous quartzite beds, the latter well exposed in the bed of a creek, which passes the mining camp one-quarter mile further north, and is not far off from the north line of the section. This quartzrock series is full of seams of limonitic ore, but none of them are large enough to begin mining operations.

I observed a similar succession of rock beds in various other localities in this vicinity, particularly in the south half of Sec. 4.

The slate rocks of L'Anse which are outcropping in many places along the Houghton & Ontonagon R. R., and evidently compose a portion of the mountains on which the Taylor mine is situated, I could never see coming in contact with these ore-bearing beds. Taking in consideration the topographical distribution of these rocks, it appears to me probable, that the slate formation succeeded immediately beneath the Taylor mine group, as it is north of the Taylor mine, and dips south under its layers. Small deposits of hematitic iron ore and siderite occur within the roofing-slates, near the slate quarries of Huron Bay, about a half mile lower down the creek bed. The belt is about thirty or forty feet wide and the ore is mingled with decomposing cherty limestone layers, probably resulting from the decomposition of sparry carbonate of iron, as some of the hematite is found in the form of spar crystals. Practically these ore deposits have no value. Brittle, dark brown, flinty layers are found intermingled with the slate-rocks adjoining this belt on the south side; on the north side of it are bluish-gray arenaceous argillites, interlaminated with similarly dark colored granular quartzite ledges. North of these, a belt of white granular quartzite, 400 feet wide, follows; farther north gray, drab, reddish or yellowish colored slate-rocks, much softer than the roofing-slates, follow each other all the way down to the shore of the bay, in a belt not far from a mile in width, of which a description is given in the previous report. Numerous dykes intersect the slate-rock series; some, particularly the narrower ones, often not over a few inches wide, consist of a fine-grained, almost aphanitic compact mass of greenish-gray color, which under the microscope appears as a turbid, little transparent, granular mass, in which clear prisms of very minute size are disorderly scattered in great quantity. Larger dykes of coarser crystalline structure exhibit under the microscope the composition of the ordinary diabasic dyke masses, met with in all horizons of the Huronian group. Clear prismatic plagioclase crystals, in intermixture with augite, transparent with brownish color, and some granules of titan-iron or of magnetite, are the constituents. Part of the augite is externally changed into viridite.

A coarsely crystalline diabase dyke, thirty feet wide, forms a conspicuous hillock on the north side of the Houghton & Ontonagon R. R., 200 steps off from the road, and about midway between the fifty-eighth and fifty-ninth mile post; the strike of the belt is east and west; it intersects a coarse breccia of white quartz fragments and some granite fragments, cemented by a dark, greenish gray colored silico-feldspathic mass; above the breccia belt, succeeds a compact, fine-grained rock belt of delicately laminated structure, which lamination becomes very obvious on weathered surfaces. It consists of the same dark greenish colored silico-feldspathic material as the cement of the breccia belt; weathered surfaces lose their color or become white. In its course the dyke comes in immediate contact with this upper belt and seems to have had the effect of making it much more compact and hard on the contact line; the higher layers of this belt gradually change from the compact into a fissile slaty form, and next succeeding to these are genuine roofing-slates. The dip of all this conformable succession of sedimentary layers is southward. A good quality of roofing-slate is also uncovered in trenches made next to the railroad, near the sixty-first mile post, counting the distance from Marquette.

Rocks analogous with those at the Taylor mine extend on the south side of the Houghton & Ontonagon R. R. in a broad belt westward from Lake Michigamme. Thick drift deposits cover the surface in that part of the country; rarely the underlying beds are naturally exposed, but numerous exploring pits, dug within the past five or six years all over this tract of land, give ample occasion to observe the succession of beds.

The strata dip south under a high angle. Graphitic slates are the lowest ones denuded; they amount to considerable thickness. Above them follows a large series of thinly laminated, flinty or granular quartzite strata in regular banded alternation with similarly thin seams of limonitic iron ore more or less contaminated with siliceous matter. Within this series locally occur larger seams widening into pockets from twenty-five to fifty feet in width, and traceable for several hundred feet lengthwise, which consist of soft, crumby, limonitic ore, almost free of intermingled quartz seams. They average in the furnace from fifty to fifty-five per cent in metallic iron; but like in all ores taken from this horizon, the amount of phosphorus is larger than admissible for the use of this iron in the steel manufacturing processes. South of the ore-bearing layers, banded, ferruginous quartzite strata extend for some distance, interstratified from time to time with dark, pyritous, slaty layers. South of them again graphitic schists occur, but I did not ascertain whether

such repetition of the strata is caused by their plication or by an actual repeated succession of similar beds.

This same complex of rock beds is seen continued on the east side of Michigamme village, and is in direct connection with the large display of the same formation on the hills north of the Champion mine, in which places the Northampton, Dalliba, and a great many other mines have been opened recently and produced a large amount of ore for the market, but at present the depression in the value of iron necessitated the suspension of work in most of them.

On the east side of Michigamme, these strata are much more impregnated with actinolite than on the western continuation of this belt. On the landspur projecting into the lake, across the north part of Sec. 28 and the north half of Secs. 27, 26 and 25 of T. 48, R. 30, a large belt of actinolite-schists, richly impregnated with magnetic granules and banded by solid seams of magnetic ore, which belt most likely corresponds with the actinolite-schists directly overlying the ore-bearing strata of the Michigamme mine, forms the lowest layers exposed; their dip is northward. Above them succeeds conformably a large series of graphite-schists, which farther north disappear in the bottom of a swamp, north of which granite and diorite bluffs briskly ascend, or in some places before we come to the granite bluffs, strata of the red jasper-banded rocks, alternating with bands of siliceous specular ore, are found to lean on these with southern dip.

Towards the east end of Michigamme Lake, the before mentioned belt of graphite-schists is found to be overlain by the limonite-bearing, banded quartzrock layers laid open in the mining pits west of Michigamme and south of the railroad, in which, a short distance east of the lake, miners have done a great amount of work. The oldest and most important mining pits in this eastern part of the ore-bearing series are the Northampton and Dalliba mines, the first situated in the S. E. ¼ of Sec. 30, T. 48, R. 29; the latter in the S. W. ¼ of Sec. 29.

The succession of beds is favorably exposed on the sidetrack of the railroad leading to the mines. At the base of the south slope of the hillside, gray-colored, compact quartzite beds, or in place of them a coarse breccia of quartzite fragments of various color, firmly cemented by a dark colored, schistose, interstitial mass, are seen as the lowest; they are in an almost upright position and dip north. Next above conformably succeeds a belt of well laminated, banded, quartzose, actinolite-schists, richly impregnated with magnetite granules; the width of this belt is about 100 feet. North of the actinolite-schists a space of about 200 feet is covered; on the springy surface a sheet of bog iron has formed.

Ascending further, we come to a belt of almost vertical layers of graphite-schists, about 100 feet wide; their dip is south. In conformable succession, underlying them, follows a belt not less than 200 feet in width, of heavy, gray colored, quartzite beds interlaminated, from time to time, with seams of graphite-schists. Then again, a drift-covered space intervenes near the brow of the hilltop; farther back on the plateau crops out again a large body of steeply erected graphite-schists, dipping northward. They form the foot-wall of a still larger series of the banded, jaspery quartzrock, in alternation with similarly narrow bands of limonitic ore and interstratified with schistose argillitic beds more or less intensely impregnated with hydrated oxide, besides seams of pure limonitic ore, which widen locally into large pockets. This ore is partly soft, crumby, ochreous, partly forms compact, aphanitic masses with smooth, conchoidal fracture; much of the ore occurs also in the radiated crystalline form of grape ore, composing stalactites of great beauty, which are, on the surface, heiter covered with a smooth, brightly shining, black, varnish-like cuticle, or this cuticle has a brilliant velvety lustre, or else larger scaly and needle-shaped crystals of goethite cover their surface. Druse cavities are sometimes lined with radiated clusters of quite large crystals of goethite and with colorless quartz dihexahedrons. Proceeding from the Northampton pits northward across the strike of the formation, we observe that the strata have suffered repeated plications into synclinal and anticlinal folds, as we find next north of the mine repetitions of the same beds in an inverted order and dipping southward, and then again the same series dipping northward for a second time. North of these folds, in which ore beds are disclosed, another anticlinal arch is formed by graphite-schists and by underlying, compact, gray colored, heavy quartzite ledges, identical with the beds exposed south of the Northampton pits. The northward-dipping part of this anticlinal fold forms the northern slope of the hill range, but towards the base of the hills the strata disappear beneath drift deposits. A head branch of the Escanaba River washes the foot of the hills, and on the other side of the channel, within short distance, a granite range faces the river with vertical cliffs. The same succession of beds, bent into repeated folds, is observable by starting from the old Champion furnace, across the hill range to the location of the Dalliba mine.

The bluffs at the furnace are composed of dark actinolite-schists; overlying them are graphite-schists, interlaminated with compact quartzite beds, which strata cover a wide belt, but toward the top of the hill-plateau drift deposits hide the rock ledges, until after a while another undulation of the surface caused the denudation of actinolite-schist, graphite-slates, quartz beds, etc., and so on to the mine, which is opened in the continuation of the Northampton belt, and needs therefore no special mention.

East of the Champion furnace the lithological character of the geological horizon soon changes. Actinolite ceases to be an important constituent of the lower beds, the graphite slate-rock series continues to be well developed for a number of miles further east, but of limonitic ore deposits in that horizon, nothing more is observable in that direction. The strata subjacent to the graphitic schists, and above the iron-bearing rock series of the Champion and other equivalent mines, amounts to a very great thickness. These beds are all well laminated, of sedimentary origin; by recrystallization of the material the rocks have become very compact, like eruptive rock masses, particularly in the lower horizons; the higher beds have generally a slaty structure. High bluffs of these rocks are exposed in the hillsides on both sides of the railroad between the Champion mine and the Washington mine, and onward to Clarksburg. The compact, crystalline rock beds of this group consist of a granular, siliceous and feldspathic groundmass, almost invariably intermingled with a large proportion of carbonate of lime, or also dolomite or siderite, and besides, the mass is always plentifully interspersed with chlorite and mica scales; often also an abundance of green hornblende prisms is unequally scattered, or more concentrated within certain seams of the laminated rocks which exhibit often serpentine corrugations throughout their mass. Very generally a part of the ledges in the succession has the structure of a breccia composed of small fragments, but occasionally enclosing larger segments of a banded succession of several superimposed layers of rock; the cemented rock fragments appear sometimes corroded on the periphery and merge with the cement mass without a sharp line of demarcation. The great amount of lime in the composition, which readily dissolves on exposure of the rock, causes it to weather with a very rough, cavernous surface, and in cases where siderite is substituted for carbonate of lime these cavities and cells of the weathered rock are found replenished with ochre of yellow or brownish red color.

On the north side of Clarksburg larger lenticular seams of a whitish colored compact dolomitic lime-rock are found, interstratified with the just described rock masses, which project there in a long row of vertical bluffs divided into several terrace-like offsets. In the same locality also a branching dyke of a fine-grained diabase is seen to intersect the strata. As before stated, the higher beds incumbent on this series are all slatelike, consisting of a fine-grained feldspathic and siliceous groundmass, crowded with minute mica scales or else chloritic scales. The mica and chlorite scales impart to many of the layers a satin lustre on the slaty cleavage planes usually intersecting the sedimentary lamination under an angle, which latter is often indicated by stripes of different color. In this upper slaty series, for the lower 300 or 400 feet, the dark green color of the rock belt below is not often seen; lighter gray tints, shading into bluish, brownish, reddish or a banded alternation of such colors, are most common, but the color of the highest beds in the succession is black, from carbon or graphite combined with the rock material.

The uniformity of this slate-rock series is interrupted from time to time by interstratified quartzrock belts, light colored or dark brown, by ferruginous matter, but actual deposits of iron ore, which farther west occurred in association with these graphite-slate layers are, as I had previously remarked, no more encountered east of the township, R. 29, on north side of the Houghton & Ontonagon R. R. South of that road, along the course of the Escanaba River, where analogous slate-rock and quartzite strata are found in isolated outliers, spread over an area generally composed of granite rocks, rich limonitic and partly hematitic ore deposits are found in association with them.

The Cheshire mine, formerly known by the name of the S.

C. Smith mine, from its discoverer, is working such a strip of slaty and quartzose rock beds, known to extend along the valley of Escanaba River for a distance of nine miles, from the N. W. corner of Sec. 19, T. 46, R. 26, to the center of T. 45, R. 26. Farther south similar iron-bearing rock beds occur in the vicinity of Little Lake. The old pits of the Cheshire mine were opened in the N. W. ¼ of the N. W. ¼ of Sec. 20, T. 45, R. 25; the presently worked pits are in the S. E. ¼ of the S. E. ¼ of Sec. 18 and in the S. E. ¼ of the N. W. ¼ of the same section. The surface in these localities is generally covered with drift; natural outcrops are very limited.

The following succession of beds is observable in the mining pits: Trending to the northwest and dipping northeast are lowest, black graphitic slate-rocks, some very fine-grained, homogeneous, other seams arenaceous, by copiously intermingled quartz grains. At intervals compact, dark colored granular quartzite ledges are interlaminated. This series reposes on a dioritic rock belt. Next above the graphitic slate belt follows a series of light colored quartz ledges and of banded jaspery layers, with alternating lighter and darker brownish colored seams. The greater portion of these quartzrocks is shattered into small fragments and firmly recemented into a breccia. Incumbent are rough cellulose cherty quartz beds, the cell spaces filled with yellow ochreous matter, above which a broad belt, irregularly widening and contracting, is formed by a crumby, not distinctly stratified accumulation of brown limonitic iron ore of dull earthy appearance, with interspersed harder concretionary masses of open cellulose structure, consisting of martitic ore granules of metallic steel-gray color, the cell cavities of which are often lined with a velvety coating of goethite, or totally replenished with radiated-fibrous clusters of this mineral. In some portions of this ore belt occur also lenticular accumulations of impalpably fine scaly hematite ore of bright, purple colored satin lustre, which, without any further preparation would answer for paint of the bronze type. The hanging of the productive ore seam is made up of a large, very much distorted and corrugated or broken up and faulted succession of ferruginous chert beds, partly in thin, flaggy layers, partly thick-bedded and cellulose, which group of siliceous rocks encloses many irregular lenticular seams of ochreous limonite, of the granular metallic shining martite, in soft friable masses, like the blue ore of the Menominee region, and of red hematite ore, soft, or in compact masses.

The larger seams of ore in this upper series of beds are mined out and furnish, taken together, nearly as much ore as the underlying belt. In the lower part of the hillslope, after short interruption of the exposures, graphite-schists are naturally exposed, in a conformable superincumbent position with regard to the described series of the pits. A mining tunnel opened on the northwest quarter of Sec. 18 gives another opportunity to observe a cross-section through the group of beds. The entrance is at the base of the hillslope, only a few steps from the bed of Escanaba River. In descending order it intersects, first a belt of graphite-schist, forty feet wide, in steeply erected position; next below, a much larger belt of gray and red colored micaceo-argillitic schists follows, then comes a belt of quartzrocks, near 200 feet wide, some ledges of which are thick, heavy, but the majority consists of a banded, thinly laminated series of alternately lighter and darker colored jaspery seams, and the greater part of this rock belt is shattered into fragments with more or less faulted dislocation of the corresponding broken ends of the layers, but without causing a chaotical disorder and dissolution of the beds, which are solidly recemented by infiltration of iron ore into the small fissures and larger crevices between the fragments. These reticulated seams of ore are partly an aphanitic compact brown colored limonite, mingled with radiated grape ore concretions, partly the cementing ore masses are purplish gray with metallic lustre and consist to great extent of hematitic oxide and of goethite, which mineral occurs in solid radiated crystal bunches or as velvety incrustation of the grape ore concretions. The larger seams of ore in this shattered rock belt are mined to advantage, but the greater portion of this excellent ore in the network of smaller seams is unavailable, as there is no way of separating it from the quartzrock. Underlying this brecciated ore-bearing quartzite belt, are the graphite-schists interlaminated with arenaceous seams and black colored compact quartzite beds, which were described as being the lowest in the cross-section of the other mining pits, in contiguity with a diorite belt and close to granite outcrops.

In Sec. 19, T. 46, R. 26, where Mr. Lonsdorf made explorations for iron in the same group of deposits, as the lowest beds reposing on granite, again graphite-schists occur, which are interlaminated with quartzite layers and enclose also irregular lenticular seams of limonitic iron ore; much of this belt is broken up into fragments, which became recemented again by infiltration of limonitic iron oxide.

Above these layers a belt of micaceous-schistose quartzites follows, brown colored by impregnation with hydrated oxide of iron, and the uppermost rock ledges observable in the locality are thick compact beds of a reddish colored granular quartzite. The general surface rock of the surrounding country is granite, associated with diorite belts intersecting it. The granite masses underlying the sedimentary beds in this locality are usually in progress of decomposition, whereby the feldspar has changed into a soft kaolinitic substance. The ore deposits found there were not sufficiently large to promise to be of much value for the miner and the work had been abandoned at the time of my visit to the place.

Reviewing the southwest part of the Michigan territory in Lake Superior region, where, as stated in my previous report, areas, many hundred square miles in extent, are covered with the upper series of the Huronian sedimentary layers, in which immense deposits of limonitic iron ore were discovered, I find during the past few years the number of such discoveries vastly augmented by the unremitting zeal of explorers, although their disappointments much outnumber their successes in their hard and expensive work. This younger group of sediments, enclosing limonitic ore deposits, shows by its topographical distribution an independence from the preceding lower strata, which proves considerable changes in the ocean level during the time intervening between the deposition of the first and the latter.

In the Quinnesec mining district no interruption in the progress of formation of sedimentary layers is indicated, as we find on the north side of the Quinnesec iron range its latest strata, the great belt of compact siliceous limestones, conformably succeeded by this very large group of sericitic argillite-schists, graphitic slate-rock layers, chert and quartzite belts, with interposed accumulations of limonitic iron ore, but further northwest, partly on Wisconsin territory, the most common case is to find this upper series of rock resting on dioritic and granitic masses, and none of the lower strata developed. Among the recently discovered productive fields for iron mining, the vicinity of Crystal Falls has become famous for its wealth in ore. The formation enclosing the ore deposits, has there a great thickness, but its determination by actual measurement is impossible on account of the much folded condition of the strata, and for want of connected exposures transverse to the stratification. Estimating its thickness to several thousand feet is surely not far beyond the truth. This folded condition of the strata is in many instances an obstacle in the decision, whether in a given locality we have under observation a descending or an ascending succession of beds.

If we follow the railroad from Crystal Falls village upward along the bed of Paint River, we find, in the first cut the road makes into rock beds, a series of hard, black slates, transversely intersected in almost vertical position, and according to their cleavage planes, dipping in southwest direction. This cross-cut is 210 steps long; thence, for the distance of 100 steps, no rock ledges are touched by the roadbed, but on the left side of the road similar slate-rocks are denuded, which apparently represent a continuation of the former succession. From here for eighty steps a cut is made through similar slate-rocks, but interlaminated with numerous quartzite seams; further on, the intersection of slates in alternation with quartz seams continues for quite a while, but these slate-rocks are more graphitic than the former and readily disintegrate, on exposure, into splintery fragments, as they contain a large proportion of iron pyrites and rusty ferruginous seams causing the decay. By this time we have reached close to the river below its falls, and find, laid open in its embankments formed by the bluffs thirty feet high, a further conformable series of graphite-schists, 300 feet wide. Beneath the graphite-schists, close to the water level at the foot of the falls, succeeds an ore belt, six feet wide at the surface, but widening to fifteen feet, followed into the hillside. This ore seam is quite heterogeneous in its composition; the bulk of it is an earthy ochreous mass, enclosing harder concretionary masses of compact limonite, with conchoidal smooth fracture, besides others formed of crystalline nodular or stalactitic grape ore agglomerations.

Another portion of the ore is found in the non-hydrated condition, either as soft earthy hematite or in compact concretions

with smooth conchoidal fracture of dark purplish color. Quite frequently such harder hematite concretions were intersected by a network of seams, consisting of fine-grained specular ore with bright metallic lustre, and cavities in these concretions were lined with lentil-shaped, purplish black brilliant crystals of oxide in association with prismatic crystals of goethite. For a short time this ore belt had been mined, but the work is now abandoned, as the close proximity of the openings to the water level of Paint River was an inconvenience, and the ore belt itself, by being followed, instead of widening, as it first did, contracted again.

Below the ore belt follows an immensely large succession of thinly laminated banded ferruginous quartz-schists of dark, rusty color, which beds, in steeply erected position crossing the river-bed diagonally, give a cause to falls eight or ten feet in height. The exposed succession of beds amounts at the falls to a thickness of over 800 feet. Intermixture of pyritous shaly seams with the quartzite beds, induces their rapid disintegration on exposure, into shelly fragments covered with an iridescent varnish-like coating of oxide-hydrate. These beds are, in the embankments on the opposite river-side, remarkably corrugated, describing in their flections perfect coils.

This is approximately the horizon in which the principal ore deposits occur in this vicinity. Not far off from the river extensive ore deposits have been laid open by the miners in the S. E. ¼ of Sec. 20, and in the S. W. ¼ of Sec. 21, T. 43, R. 32. Still more promising are the explorations of the Briar Hill Iron Company, in the S. W. ¼ of Sec. 20, and S. E. ¼ of Sec. 19, on which locations a belt of marketable ore 100 feet wide is claimed to be found. At the time of my visit, the trenches were not fairly opened, but it was plainly visible the deposits were very large and of good quality, principally limonite, but partially hematite, which is usually the case in all the ore belts of this formation.

A great many other explorations in the wider circumference of Crystal Falls could be enumerated, which met with more or less success, but to describe all these places would involve a useless repetition of the same structural features delineated previously.

Another mining center working the ore beds of this formation is near Chicagon Lake and on Iron River, which regions have, to some extent, been considered in my previous report; but since the time of my first visit to these places a vast amount of exploring work has been done there, by which the value of the already known ore deposits was more positively tested and a great many other new discoveries were made.

An uninterrupted continuity of the rock formations connects this region with the Crystal Falls region, and west of Iron River the same complex of strata spreads yet over wide areas. These parts of one and the same basin exhibit therefore, excepting unimportant local differences, a harmony in their structure, which, after one part has been examined and described, leaves little new to be reported about the other part; I can therefore be short in my further remarks concerning this region. A few new localities examined by explorers and the progress since made in the exploration of the previously described places on Iron River may be here the objects selected for illustration of the structure of the entire district.

Interesting are the explorations made under the supervision of Mr. Bordman, in the N. E. ¼ of Sec. 26, T. 43, R. 34.

The surface in this locality is covered with drift deposits; my observations had to depend therefore on the inspection of the test-pits, systematically located so as to intersect the formation transversely.

The general trend of the strata is northwest, their dip northeast, very rarely vertical; but the beds are subject to frequent plications, and often abrupt ruptures of the belts, with more or less considerable faulted location of the broken ends, are observed, which circumstances are very annoying for the miner, and an impediment for the geologist in his efforts to find out the true order in the succession of beds, which as far as I could learn is as follows: Farthest south, and consequently lowest, a broad belt of graphite-schists occurs, succeeded by a large series of banded, siliceous beds, consisting of alternating, narrow seams of flinty quartz, in different shades of brown, yellowish or reddish colors, with interposed seams of compact limonite. These beds are much corrugated and fractured with dislocation of the seams, but recemented again by infiltration of limonitic ore, of which larger pockets, locally expanding to the width of forty and fifty feet, are met with in this series.

This ore is dark, blackish brown, very compact, with aphanitic, smooth, flinty fracture; its powder is yellowish brown; it often

encloses numerous angular fragments of the quartzrocks surrounding the pockets, in proof of its secondary infiltration into crevices of the quartzose rock belt.

North of this series, a wide belt of silico-argillitic, slaty rock beds and flagstones follows, varying in different colors from light gray to dark red. Within this group of beds deposits of soft, blood-red hematite are found irregularly wedged in, some of which ore seams are large enough to be mined.

Farther north the mining pits were not extended. A chemical analysis of the compact, limonitic ore of this locality gave, in 100 parts of the ore, 88 parts of iron oxide, 10 parts of water, and not quite 1 per cent of insoluble, siliceous matter; but the proportion of phosphoric acid was unusually large, amounting to 1.7 per cent of the ore.

The explorations in the localities on Iron River which were mentioned in the previous report, have since that time been vigorously continued with great success. In the N. W. ¼ of the N. W. ¼ of Sec. 36, T. 43, R. 35, a limonitic ore belt, from 80 to 100 feet in width has been discovered, and its extension lengthwise is traced for 900 feet. A similar belt of good limonitic ore, 32 feet wide, has been laid open in the southwest quarter of the same section.

Equally rich ore deposits were found on Mr. McKennan's property, in Sec. 26 of the same town, and other explorations in progress in the same neighborhood promise similar favorable results. The nature of these ores is in all the localities pretty much alike. Soft and compact limonite, mingled with crystalline grape ore concretions, forms the great bulk of the deposits, but in nearly every one of these localities, also red hematite ore masses occur in association with the limonite.