GEOLOGICAL SURVEY OF MICHIGAN
LUCIUS L. HUBBARD, STATE GEOLOGIST

UPPER PENINSULA
1881-1884

VOL. V
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

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Contents

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 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.

*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 years 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.

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

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 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 foramaniferous 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 hydro-micaceous 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 live 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 ill 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 conies 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 super-position 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 paramophosis.

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 accomplish eel 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 con-founded 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 exceptionallv 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 lingers 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 Hot 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 out- crops, 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 quarts, 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 south- ward 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 interlanimated 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 brig-ht 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 inter- mingled 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 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. J udging 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 conies 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 interlanimated 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 quarts 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 hike, 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 conglomerate, 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, scarcety 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, interlanimated 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 nom-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 held 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 arc 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 conies 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 facsimile 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 live miles, further on, these gabbros tire again repeatedly intersected by the roadbed. This gabbro belt can be traced in continuous exposures south- westward 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 quarts 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 quarts 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 under- lying 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, inter-stratified 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 shelly 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.

CHAPTER VI. MICA-SCHIST FORMATION.

REGARDING the age of this group, which I had but little examined at the time I published my previous report, I had to change essentially the opinion I then held, which changes of my views I have already expressed on several occasions, in the previous pages.

Seeing, for the first time, this large series of beds which borders the south shore of Lake Michigamme, opposite the village, dipping south in conformity with the strata of the Michigamme mine, and observing in the intermediate space a wide belt composed of graphite-schists and banded, ferruginous chert beds, inclosing seams of limonitic iron ore, dipping in conformity with the rock series north and south of it, I unhesitatingly accepted the theory of Major T. B. Brooks, who represented the mica-schist as the youngest sedimentary deposits of the Huronian group, thinking the just mentioned succession of beds to be an uninterrupted series of layers, of which the most southern were the highest. This same locality, previously under consideration while I gave a description of the Magnetic mine and tried to determine the relative stratigraphical position of this ore-bearing belt of rocks, as I stated then, on more careful examination furnished satisfactory evidence, that the mica-schists in this cross-section are the inferior strata on which the limonitic and graphitic group of beds conformably rest.

This evidence consists in the clear recognition of typical garnet and staurolite-bearing mica-schists, on the north side, and conformably underlying the graphitic and limonitic group of rock beds, which northern belt of schists lithologically is identical with the mica-schists on the south side of the belt of graphitic and ferruginous rocks. This seeming repetition is accounted for by a folding of the layers by which the incumbent youngest strata became wedged into a synclinal depression of the older.

The mica-schists of Michigamme Lake, according to this exposition, have their place in the middle horizon of the arenaceous slate group, and their consideration as a separate group of beds, younger than the others, should have been entirely discarded, but as the clear conception of the true position of these beds is a recently made progress which I made after this whole report was nearly completely written out, I retained the adopted method of communicating the recent results of the work of the Survey under the form of supplementary notes to the preceding volume, making in each place the necessary rectifications instead of undergoing the labor of a radical change in the arrangement.

After these explanatory remarks, the further information I have to give about the mica-schist group, in this and other regions, might as well be here expounded separately, as to be patched into the former chapter, comprising the arenaceous slate group, where it actually would belong.

A very good exposure of a descending section from the typical staurolite-bearing mica-schists down to the dark green colored garnetiferous biotitic and actinolitic schists analogous to those superincumbent on the ore-bearing belt of the Magnetic mine and likewise to those found largely displayed on the north side of the Keystone mine, of which a description is given in the previous report, occurs in T. 47, R. 30, Sec. 4. On an island in the south part of Lake Michigamme, the mica-schists of gray color, with silvery lustre, full of staurolite crystals, are largely exposed, dipping under a high angle to the west. A short distance east of this island is another smaller one, perfectly denuded of soil, formed of dark green colored biotite-schists, full of reddish colored garnets from the size of a pin's head to that of a hazel nut. They dip westward in conformity with the beds of the first island. Not over 200 feet east of this island is the main shore, on which a conformable series of dark gray colored compact quartzose mica-schists continues for the distance of about 200 steps transversely to them. The lower part of this series is a breccia, consisting of a granular micaceo-actinolitic dark colored groundmass, in which numerous angular fragments of well laminated, banded, lighter colored, siliceous rock are imbedded. Beneath the breccia follow dark blackish green coarsely scaly biotite schists, very much twisted and corrugated; they are locally crowded with reddish garnets; other times a large proportion of dark green hornblende prisms helps to compose them. Interlaminated between these biotite schists are bands of well laminated, fine-grained siliceous substance. Portions of this rock belt consist of a crystalline hornblende rock of massive appearance, but it is merely a more compact modification of the other sedimentary beds. A belt of this hornblende rock projecting- in cliffs on the shore line, is in the manner of an amygdaloidal rock, permeated with concretions of calcspar, which on the exposed surfaces has been washed out and leaves them perforated with cavities anastomosing as the holes in the coarser kind of sponge.

In the described locality a wide dyke of diabase is seen to intersect the strata transversely. The exposures do not continue further east into lower beds. A striking similarity exists between the lower portion of the described rock series and the rocks overlying the ore-bearing strata of the Magnetic mine; and not less perfect is their resemblance to the rock complex composing the hillslope on the north side of the Keystone mine. I consider them therefore as the representatives of the same geological horizon.

On Devil's Island, in the S. W. ¼ of Sec. 27, T. 48, R. 30, not far off from the north shore of the lake, the mica-schists, which there have a northern dip, are intersected by a large dyke of coarsely crystalline diabase, which holds a considerable proportion of olivine grains in its composition.

The strata exposed north of the island, on the main shore, are graphite-schists and actinolite-schists, impregnated with a good proportion of magnetite. These beds likewise dip north and represent the lower portion of rock complex, which higher up in the series incloses the limonitic ore deposits; it corresponds with the strata exposed at the Champion furnace. At the extreme east end of Michigamme Lake almost vertically erected, very much corrugated, well laminated rock ledges crop out, dipping to the north, which, in their lithological character, correspond with the mica-schists. The strata on the north side of the railroad track at this place, belong to the lower series of the Northampton mine rock-complex. The mica-schists in all probability continue eastward past the Champion mine, occupying the bottom of the valley, but are not exposed; the underlying series of the rock beds of which above a description is given, is traceable on the southern row of hills, all along unto the Keystone mine, where the group of beds is extensively exposed. The large rock bluffs in Sec. 4, T. 47, R. 29, on the south side of the railroad, which I have previously described as well laminated compact gritty rocks, consisting of a micaceous quartzose and feldspathic groundmass, which generally contains also a good proportion of carbonate of lime and in certain seams is crowded with green hornblende crystals, in many respects resembles certain belts of the mica-schists exposed on the islands in Michigamme Lake; their stratigraphical position corresponds with that of the mica-schists. Tracing these rock belts farther east, their lithological character changes more and more, and the horizon of the mica-schists is no more recognizable.

If I am correct in placing the slate-rock formation of Huron Bay and near L'Anse as the strata next succeeding below the ore-bearing rock series of the Taylor mine, their position would correspond with the relative position of the mica-schists; the difference in the material of the two groups, one consisting prevailingly of gritty arenaceous material, the other more of impalpably fine mud sediments, is not of so great importance as to preclude their contemporaneous deposition under different local circumstances. The mica-schists seem to continue southward along the course of the Michigamme River, as we find in its lower course, five or six miles north from its entrance into the Brule River, and from there down to the mouth, mica-schist to be the prevailing surface rock. Along the lower course of the adjoining Paint River the mica-schists likewise are the only rocks seen in the exposures, and from the Michigamme downwards, almost to Badwater village, these same rocks are, except some eruptive diorite masses, the exclusive surface rock splendidly exposed in the river bed and in the hillsides bordering the river.

A good many miles northwest from the indicated localities, in the vicinity of Crystal Falls, this same rock must be somewhere at the surface, as I found at Crystal Falls in the drift a number of large angular blocks of the mica-schists full of staurolite crystals.

A description of the rock outcrops, from Badwater village up to the mouth of Michigamme River, I have given in the previous report, on pages 204 to 207, likewise of the outcrops for about a mile above in the Brule River.

At present I will describe the continuation of the cross-section the river makes through this formation, beginning at the mouth of Paint River and following the Brule River downward to the place which formed the end point of the previously described part of the valley.

At the mouth of the Paint River, the valley is a narrow gorge; the southern hills are eruptive diorite masses, against which the strata of the mica-schist formation abut unconformably with southern dip. Proceeding from here down stream, we ascend into higher beds of the series, which amount to much over one thousand feet of strata, until lower down the river a broad eruptive diorite belt diagonally crosses it. On the other side of this diorite belt, we have reached the above mentioned end point of former examinations.

The lowest beds seen at the mouth of Paint River, are an alternation of silvery shining minutely scaly mica-schists, partly in smooth fissile beds, partly corrugated into small wrinkles and also into larger plications with more compact gritty rock ledges, composed of a fine-grained mixture of quartz granules with grains of feldspar and with small brownish biotite scales. Most of these beds are gray colored, but also red seams occur, in which the feldspar grains (red orthoclase) prevail over the quartz grains.

This lower group of beds has a great thickness, as can be observed by following the Paint River from its mouth upward, where many hundred feet of strata are intersected by it, without an essential difference in the character of the ledges in any position, from one end of the exposures to the other.

The higher series exposed on the Brule River, below its union with Paint River, consists of comparatively softer schistose layers than the former; their composition is like that of the former rock, a mixture of quartz and feldspar granules with biotite scales in different proportions; if the mica prevails, they have a satin lustre; by prevalence of the quartz and feldspar sand, they are dull gritty. The color of the first 300 or 400 feet of beds is light grey, shading into greenish or reddish; in most of them the feldspathic component is more or less completely changed into kaolinite, and on exposure these beds soon disintegrate into a shaly heap of rubbish.

Higher up in the series, the schists have a dark greenish steel-color, with considerable lustre; their color is due to the green color of the biotite scales in the rock substance.

Here and there, at this horizon, layers of quartzite are found interstratified.

The succession of the dark, greenish colored beds is very large. Some are cleaving like roofing slates, shining; others are dull, earthy in appearance, olive-colored. With these are interlaminated intensely red colored schists, by impregnation with hematite, some of them impalpably fine and homogeneous in their mass, others composed of coarse mica scales and kaolinized feldspar grains of white color, mingled with the hematitic and argillitic fine-grained or gritty quartzose groundmass.

Farther down stream, greenish colored, less schistose, bulkier rock beds, formed of a fine-grained mixture of feldspathic quartzose and micaceous composition follow in the succession, and soon after, this sedimentary series comes in contact with the before mentioned dioritic rock belt crossing the river. These last sedimentary beds seem to be formed of the detrital material of the diorite which, on its surface, is much decomposed, and friable by the pressure of the hand into crumbs.

The schists, richly impregnated with hematite, have here attracted the attention of explorers and on both sides of the river their abandoned pits are seen. The explorations on the Wisconsin side are known by the name of Ellwood mine, those on the Michigan side were undertaken under the superintendence of Mr. Bordman.

No ore seam of any value was discovered in either of the two localities. Smaller pockets of compact limonite were found accumulated in the surface of these rotten diorite masses, joining the schists, and in crevices of that rock, which evidently originated from secondary infiltration of iron solutions at the time the decay and disintegration of the diorite had already begun. The vicinity of the Ellwood mine is interesting, as we find at this place the before mentioned mica-schist series, succeeded by younger schistose deposits, interlaminated with banded, ferruginous quartz-rock seams and belts of graphite-schists, which group of beds corresponds with the lower strata of the Commonwealth mine, or the Florence mine, and with the large group of rock beds denuded in the test-pits near Keyes Lake, which have been described in the previous report. It is one of the rare instances in which the superposition of the Commonwealth group on the mica-schists is clearly observable.

Quite large exposures of the mica-schist group occur in Sec. 27, T. 42, R. 32, and in the whole southeast quarter of this township; the greater part of the strata correspond with those exposed at the mouth of Paint River; certain beds are crowded with staurolite crystals and garnets and in the succession a large belt of a coarsely brecciated rock is observable, which incloses fine-grained, red colored rock fragments, consisting principally of orthoclase and quartz grains.

The strata in this locality are very much dislocated and dip in different directions. North of the exposures, not much over half a mile apart from them, project isolated hillocks of granite, and a half a mile west of them, separated by a drift-covered space, we find high bluffs of nearly vertically erected beds of the ferruginous quartz-schists of the Commonwealth group, which, from there, is the surface rock, without interruption onward to Chicagon Lake and Iron River.

Another very large complex of schistose rock beds, resembling to some extent the mica-schists of Michigamme, though not strikingly, occur in a similar relative position in the Gogebic district. The fine-grained groundmass of the schists in the Gogebic region is more of feldspathic than of quartzose nature, and the mica in them rarely prevails so as to give them as bright a lustre as those Michigamme schists have. They approach in their character almost as near to the Huron Bay slate-rock formation as to the typical form of schists on Michigamme Lake.

This schist formation which I observed principally near the south end of Gogebic Lake, had been previously described by me in connection with the magnetic actinolite-schists in Secs. 12 and 13, of T. 46, R. 42, which they conformably overlie, and needs therefore no repetition. The mica-schists in the Penokee region described by the Wisconsin geologists as staurolite-bearing, I have not had occasion to examine; those at the south end of Gogebic Lake, I think, contain nothing of this mineral.

CHAPTER VII.
KEWEENAW GROUP.

(A) GENERAL CONSIDERATIONS.

THIS immensely large succession of arenaceous and conglomeratic sedimentary deposits, interstratified with crystalline diabasic rock belts and with belts of porphyry, is peculiar to the Lake Superior region, and as it composes the entire Keweenaw Peninsula, this rock formation has been named after this landspur; otherwise it is also known as Copper-bearing group, as it forms the repository of an unusually great wealth in metallic copper.

The occurrence of large loose masses of copper, found in this region on the surface, or in the bed of rivers, was made known by the earliest travelers who visited it, and since that time this reported mineral wealth has attracted considerable attention to this land of promise. Particularly within the last fifty years the entire district has been searched over by explorers and by geologists, and became well known in its general geological features by the descriptions of these men; a great amount of more special information has been added to it daily, by actual mining operations undertaken in all parts of the district.

Under these circumstances, the report I give of the geological structure of this country, which I examined during the time of two summer seasons, does not, and can not pretend to be the result of original observations of myself exclusively; the greater part of it has to be a repetition of previously well known facts. But as by the miners constantly new discoveries are made, which have a bearing to elucidate points in geology, before not fully understood, the collection of this additional knowledge, together with the few advances in the conception of the natural history of this rock group, which I could make by my own efforts, I hope will do some good, at least in promoting information.

The topographical extent of this formation is in close relationship with the shape of the basin of Lake Superior. It forms, taken in its totality, a synclinal trough, the axis of which almost coincides with the longitudinal axis of the lake; a large portion of this rock formation must therefore be buried beneath the level of this great water basin.

Of the southern rim of this trough, on the shore of Lake Superior, not a trace is found east of Keweenaw Point, with the exception of the submerged cliffs of Stannard Rock, which consist of a reddish brown colored compact amygdaloidal rock, agreeing in its character with other trappean rocks of the Keweenaw series. Also, of the northern, southward-dipping rim of the trough, in the east part of Lake Superior, only a few isolated patches occur on the Canadian shore, or on islands near the shore, as on Mamainse Point and on Michipicoten Island.

The first larger development of this rock group is found recorded on the geological maps of Canada, at Nipigon Bay, Black Bay and Thunder Bay, where the formation is not confined to the shore part only, but extends far up to the north end of Lake Nipigon. The island, Isle Royale, belonging- to Michigan, makes a part of this northern, southward-dipping part of the trough.

East of Thunder Bay, on the Canadian shore, older rocks representing the Huronian series, border the lake, but beyond the Canada boundary lines, south of the mouth of Pigeon River in Minnesota, the Keweenaw group occupies a broad belt, adjoining the lake all the way down to Duluth, dipping under moderately low angle to the southeast. From Duluth the extension of this group in a southwest direction has been ascertained to the head waters of St. Croix River, where it disappears under Silurian sandstones.

Wisconsin geologists inform us of the composition of the dorsal part of the Bayfield Peninsula by the Keweenaw group, dipping south and consequently representing a part of the northern rim of the synclinal trough. From the same source we learn the extension of a belt of the Keweenaw rock series from the headwaters of the St. Croix River parallel with the other, striking northeastward and dipping northwest or north. The inclination of the strata of this belt near the St. Croix being comparatively flat, increases as we follow it eastward. At Montreal River, where the formation comes up to the shore of Lake Superior and enters Michigan, the ledges of it stand almost vertical. Thence, continued in eastern direction to the north part of Lake Gogebic, it gradually loses in steepness of its dip; the belt widens here considerably, composing the very broken country of the Porcupine Mountains. From Gogebic Lake an uninterrupted belt of the formation, striking in northeast direction, extends to the end of Keweenaw Point under the form of a prominent ridge, following the shore at some distance, and after crossing Portage Canal, occupying the entire width of the peninsula.

Another isolated range formed of the Keweenaw rock series, known as the South Copper Range, starts from the southeast end of Gogebic Lake and extends eastward for thirty miles. Farther east, in the valley of Sturgeon River, an outlier of the formation composes the so called Silver Mountain. The intermediate depressed space between the north and south ranges, drained by the west branch of Ontonagon River, and farther east by the Sturgeon River, is superficially covered with drift masses, but under the drift horizontal layers of Silurian sandstone seem to cover the entire area. The horizontal sandstones are, in many places, seen unconformably abutting against the foot of the brisk rock walls of the north range of the Keweenaw group, which present themselves on its south side, all along its extension from Gogebic Lake to Portage Lake. West of Gogebic Lake the Copper Range exhibits likewise brisk escarpements on its south side, but there the different members of the Huronian series are seen to underlie the Keweenaw group conformably, dipping northward with the same inclination.

The Huronian beds, in contact with the diabase belts of the Copper series, are not always the same, once lower ones, another time higher ones, which proves an erosion of the Huronian layers before they became covered with the diabasic overflows; but the conformity of these beds likewise proves that the Huronian rocks were, at the time, not much dislocated and that the upheaval of the incumbent and succumbent series must have occurred simultaneously at the end of the Keweenaw period. The obviously greater disturbance and corrugation of the Huronian strata, compared with the Keweenaw group, which latter is lifted in a body without much distortion, indicates a more direct, immediate action of the disturbing forces on the Huronian beds, and a transportation of the pressure on the incumbent rocks, moderated in its impetuosity.

The disturbance of the Huronian strata did not occur everywhere in the same degree; the rocks in the Marquette region are infinitely more disturbed and broken up than the iron-bearing Huronian rocks in the Gogebic and Penokee Range.

Just the same happened with the Copper-bearing rock series, which, as before stated, near Montreal River stands almost vertical, at the Gogebic Lake dips under an angle of from 60° to 70°, at the Minnesota mine, and environs, about 50°. The same dip is observed at Portage Lake; further north it is 38°, at the Calumet mine, and near the end of Keweenaw Point, the dip of the beds is not much more than 30°,—often less.

It is also generally observable that in examining cross-sections through a large succession of strata on Keweenaw Point, the beds in the lowest position are much steeper inclined than those in the middle of the section, and these more than those on top of the series.

(1) STRUCTURE OF THE KEWEENAW GROUP—IN GENERAL

In the above introductory remarks the composition of this great succession of rock strata, of sandrock and conglomerate belts, with interstratified igneous rock masses, has been mentioned.

The opinions of geologists differ in their conceptions of the limits demarcating' the Keweenaw group from the Huronian rock series.

In the Canadian reports of 1863, the very large succession of schistose, argillitic and quartzose beds, exposed as the underlying rocks of diabasic belts at Thunder Bay and other localities, is considered as the lower portion of the Keweenaw group.

But reading their own descriptions and those recently published in Mr. Irving's excellent work on Lake Superior rocks, I find, as the latter does, a perfect lithological resemblance of these schistose layers with the group of beds which occurs on the south shore of Lake Superior and constitutes the upper horizon of the Huronian series, without contradiction from any side. Of the identity of this lower rock belt of Thunder Bay, with the upper Huronian rocks in Michigan, I became still more firmly convinced, after I had occasion to observe a continuation of this Thunder Bay series into the State of Minnesota, while crossing from Agate Bay to Vermillion Lake. The exposures observable on this route, do not only correspond with the descriptions given of the Thunder Bay series, but are at the same time a perfect counterpart of the upper Huronian of Michigan.

The conformity of this lower group of schists at Thunder Bay with the overlying series of rocks, which strata of the north shore have a much flatter dip than the corresponding series on the south shore, is in both compared regions not a perfect one, as we see lower or higher strata of the underlying group in contact with the incumbent diabasic rocks, which proves either an erosion or dislocation of the lower beds before they were covered with the others. Some interruption in the succession of rock ledges must have occurred at this period, as the entire complex of later formed strata has an essentially different lithological character from the earlier formed complex of beds, which among themselves again preserve a certain typical resemblance in contrast with the others.

The same divergence of opinions exists with regard to the upper limits of the Keweenaw group.

The large succession of horizontal sandrock beds found in contact with the Copper-bearing group on the east and on the west side of Keweenaw Peninsula is lithologically so similar to certain rock seams of the latter, that a distinction of both is difficult.

The eastern portion of these horizontal or only little inclined rock beds abuts unconformably against the Keweenaw rocks, which everywhere, as far as their extent goes, are in a more or less steep angle deviating from horizontality.

The western sandstones, identical in appearance with the eastern, and likewise almost horizontal, are also found in discordant position to the Keweenaw rocks, which is, for instance, quite obvious in comparing the strata of sandrock, composing the Apostle Islands, with the neighboring sandrock exposures, belonging to the Keweenaw series seen in nearly vertical position at the mouth of Montreal River, but on the west shore of Keweenaw, south of the entry into the canal, the western sandstones are largely exposed, having an inclination to the northwest from 10° to 12° or less. The Keweenaw rocks cannot be seen in contact with them, as a space of several miles is between them, where no outcrop occurs; all is deeply covered with drift, but the first exposures we meet land-inward, are sandstones dipping under an angle of about 25° or 30° in the same direction as the sandstones on the shore; farther on, conglomerate beds follow and finally diabasic belts, all in conformable succession. Here a conformable succession of the strata in gradually diminishing inclination could with propriety be supposed to fill the interval, but we have no actual proof of it.

The equivalency of the eastern sandstones with the Potsdam sandstone group of New York is proved by fossils found in the upper layers of the series, east of Keweenaw, and south of it, in the Menominee region, where at the Breen mines and on the west side of the Quinnesec mines, certain seams of the horizontal sandrocks, overlying discordantly the iron-bearing series, are full of lingula shells and fragments of dikelocephalus and other primordial trilobite forms. The occurrence of the same fossils in the sandstones of St. Croix River, which are the upper beds of the western sandstone series, proves the identity of the eastern and western sandstones. The Silurian age of these rocks, formerly not generally accepted, is at present no more questioned, also their position above the Keweenaw rocks is by none disputed, except by Dr. M. E. Wadsworth, who asserts to have observed the superposition of the Keweenaw rock group on the eastern sandstone, which specified localities shall be more especially considered hereafter. An open question is yet, whether the Keweenaw group is a rock complex for itself, not connected with the Potsdam group by an uninterrupted continuity in the deposits, or whether it is only an earlier phase of the Potsdam period, in which these rock beds formed.

The general character and the succession of strata in this group in different parts of the Lake Superior region, is found described and illustrated by sections and maps in the reports of Jackson and of Foster and Whitney.

Prof. Pumpelly, while engaged by the Michigan Geological Survey for the examination of the Copper district, devoted his work principally to the examination of the Portage Lake and Eagle River districts, and published in the first volume of Michigan reports a great many detailed cross-sections and maps, based on the records of the explorations made by the different mining companies; partly also such sections, with accurately measured distances, were the work of his own and his assistants. One of the largest of these, elaborated by Mr. Marvine, is the section from Eagle River to the Phœnix mine; it comprises a succession of about 8,000 feet of strata.

Comparing these sections made in different parts of Keweenaw Peninsula, it becomes obvious that certain beds identifiable by peculiar lithological characters, were persistent for long distances, and can serve as excellent landmarks for determination of the geological horizon of a locality, but as important as this is for general orientation, the widening and shrinking, and often total elimination of such belts, and the variations in the dip of the strata, cause so great differences in the relative distances from one belt to another, in different, more remote localities, that no scheme could be constructed guiding the miner reliably in his calculations to find, by measurement, the approximate position of certain beds he was looking for. Prof. Pumpelly attempted to calculate the approximate widening or shrinking of such rock belts in a certain direction, but, as could be expected, such calculations are extremely uncertain. Within limited precincts, however, environing a known, accurately measured cross-section, the miners have, with satisfactory results, used these sections as guides in their exploratory work.

The different mining companies, by continued exploration of their property have, in the course of time, considerably increased our knowledge of the structure of this rock formation, and daily new additions are made to it.

Of particular interest is the cross-cut made by the Calumet and Heel a Company. Starting from their productive conglomerate belt at the ninth level, they drove a horizontal drift at right angles with the trend of the formation to the boundaries of their property, a distance of 2,468 feet.

A similar grand enterprise, nearly finished, is the vertical shaft sunk on the Tamarack property, a half a mile west of the Calumet mine, in the expectation to meet with the conglomerate belt of the Calumet mine, which, if its dip remains as regular as it is in the mine, is calculated to be struck in a depth approximating 2,400 feet from the surface. The depth of this shaft was, on the 10th of July, 1884, 1,550 feet, and the work is vigorously pushed ahead. After its completion we will have, adding the drift in the Calumet mine to it, an uninterrupted section a full mile in width. A special description of the strata intersected by these two monuments of human industry, will be subsequently found on another page.

The series of rock beds succeeding each other on Keweenaw Peninsula, without any indication of a repetition of the strata by folding, amounts to a surprising thickness, measuring by miles, and even single belts of the series, of sedimentary origin and little differing in material or molecular structure throughout their whole thickness, are found to be a mile in width. Moreover we see on Keweenaw Peninsula neither the lowest beds of the series exposed nor the highest; what we can see is not less than 30,000 feet of strata; in other regions the thickness of the group has been estimated by some geologists to be much greater.

On both sides of Portage Lake the sequence of strata is observable for the distance of about three miles, transversely to their strike, partly in natural exposures, partly denuded by the work of miners and explorers.

The strata on the two sides of the lake do not exactly correspond; according to Prof. Pumpelly, the north side is shoved 720 feet farther west than it had to be to correspond with the south side. The dip of the rock beds is to the northwest, under an angle of about 50° at Houghton; but further west, on Swede Creek, the sandrock strata of this group dip under an angle as low as 30°, and 25° even.

Proceeding from east to west, we find the lowest exposed beds in a ravine on the property of the Isle Royal Mining Company (T. 54, R. 33, Sec. 6, N. W. ¼), where an amygdaloid belt overlain by a belt of conglomerate, both steeply upheaved, conies in direct contact with horizontal ledges of Silurian sandstones, of which the entire lower part of the hillslope is composed.

The discordant contact of the beds is plainly observable in the bed of the little creek flowing through the ravine. From this locality, beginning on the north side of the just mentioned conglomerate belt, the Isle Royal Company had, about fifteen years ago, a row of trenches dug across the strike of the strata, through the whole width of their property, for the distance of almost a mile. The record of these explorations furnished by Mr. Mabbs to Prof. Pumpelly, was used by the latter in the construction of the cross-section published by him, which, commencing in this place, was continued to embrace the entire succession of beds to the Atlantic mine, a distance of over three miles.

At present, most of these trenches are filled with rubbish, so that no occasion remains for re-examination of the details of the cross-section in this place.

In the alternation of beds, eight different belts of conglomerate occur on the Isle Royale property, none of which is very wide. The rocks intervening are dark colored, compact or amygdaloid diabases, differing some in various horizons, in grain and shade of color, but essentially they are only slight modifications formed of the same material; some of them belong to the lustre-mottled variety of diabases.

The amygdaloidal belts among the diabasic rocks, which are considered to be overflows of liquid lava streams, are no defined particular belts, but represent the foamy, porous portions of such lava streams, the cavities of which, by subsequent infiltration of mineral solutions, became replenished, partially or completely. The infiltrated contents of the amygdules are calcspar, quartz, laumonite, epidote, prehnite, analcite, datolite, chlorite or delessite and copper; sometimes only one of these minerals fills the cavity, but usually two or three of them together, whereby often it can be seen which of the minerals was first deposited and in which order the others were deposited. The quartz is sometimes in clear crystals; other times it forms a banded incrustation under the form of agate or chalcedony. The chlorite, or probably delessite, is likewise found under the form of an amorphous dark green mass, with dull fracture like tallow, or in radiated crystal concretions; this amorphous, soft, chlorite-like mineral is it which principally fills out the irregular interstitial cavities occurring nearly in all the compact masses of diabase, described by Pumpelly as pseudo-amygdules. It is often difficult to decide whether these pseudo-amygdules should be considered as secondary infiltrated substance or whether they were an original constituent of the rock, perhaps an alteration product of some other mineral which occupied the same irregular interstitial space.

The main constituents of all the diabases of the Keweenaw group are plagioclase and augite crystals, with addition of a smaller or larger quantity of disseminated magnetite granules and almost regularly of olivine. The plagioclase has often lost its transparency, and also the augite and the olivine are often altered into a green turbid substance, or into a blood-red scaly micaceous, or other times dull earthy material. Other minerals found in the combination, of which epidote is very common, are likewise paramorphic products of the original constituents or secondary infiltrations. The amygdaloidal seams of the diabase belts, of which a great number were encountered in this section across the Isle Royale property, most all carry some copper, but only a few of them proved rich enough to pay mining them. Likewise did occur various transverse fissure veins, charged with copper ore in the form of chalcocite and whitneyite; the gangue mass is quartz and calcite and siderite, but of these also none was worth mining".

(2) SOUTH SIDE OF PORTAGE LAKE.

The Isle Royale Company has at present suspended all work in their mine. The same belt is running- across the Grand Portage property and the Huron Company property, in both of which places the ore-bearing belt was mined long after the Isle Royale had quitted, but lately also the Grand Portage mine stopped work and only the Huron mine goes on, ostensibly with success.

On the Grand Portage mine another cupriferous seam, 200 feet west of the Isle Royale seam, was mined together with the other. The copper in these mines is not so often found in association with the brownish red colored amygdaloid, filled with calcspar and laumonite, as in a pale greenish, dull earthy-looking rock, sometimes compact and quite siliceous, other times porous, friable, mingled with calcspar and milky quartz seams. The greater portion of the metal found is in coarser masses, so called barrel-work, and also the stamp rock contains it in coarser form, so as to be washed without great loss. The width of the portion of this amygdaloid belt, or vein, to use the popular expression, which is taken out as the productive part, averages about twenty feet, sometimes less, sometimes more.

Examining from the Grand Portage mine westward, the same alternation of diabase belts, amygdaloidal and compact, with conglomerate belts or respectively sandrock belts, continues onward to the Atlantic mine, which is the mine situated farthest west.

According to the map of Prof. Pumpelly, between the Grand Portage mine and the Atlantic fourteen conglomerate belts occur, some of which are not over two or four feet wide, others twenty or thirty and two from fifty to one hundred feet.

Within the just described space, between the Grand Portage and Atlantic mine, a distance of two miles, a great many abandoned exploring pits and farther advanced mining enterprises are observable, and in most of them, examination of the material shows the presence of metallic copper, but the fact of their abandonment is sufficient proof that the work did not pay. On the road leading from Houghton to the Atlantic stamp mills, a large portion of this rock series is found well exposed naturally, or by cuts of the road, and by various old mining pits. Severed amygdaloidal belts attract attention there; one on the Montezuma property, close to the west side of the large diabase belt cropping out at the lime kiln or the bridge, about thirty feet wide, superficially in decomposing crumby condition, consists of rounded and angular fragments of a purplish gray amygdaloid, its cavities filled with calcspar, with zeolites and in part with epidote, and of other fragments of pale green epidotic rock masses, all cemented into a breccia by an abundant light liver-colored interstitial mass of silico-feldspathic composition of fine grain, with smooth conchoidal fracture, which exhibits the lineated banded structure of a sedimentary rock mass; it enters the superficial cavities of the enclosed amygdaloid, in proof that these cavities in the rock were not replenished with other minerals at the time it became embedded in the cement.

On the west side of this brecciated belt follow for about 200 steps, compact, diabase ledges, with irregularly intermingled, streaky seams of epidotic character, insensibly merging with the dark colored diabase mass. Within this rock belt occur also amygdaloidal seams, carrying copper and bright greenish yellow epidote crystals as filling-material of the amygdules.

Mr. P. Gottstein's candle factory is established in the old excavations made by the miners in these amygdaloid seams, which were not found rich enough to continue the drifts further into the hillside.

West of this diabase belt occurs another amygdaloid belt about fifty feet wide. It has a dark, reddish brown color, full of unusually large, irregularly lobate and anastomosing cavities, filled with laumonite or with the amorphous porcelain-like form of datolite, and is in a soft, crumby, decomposing condition, barren of copper.

A hundred and fifty steps further west, old test-pits are next to the roadside, in which a belt of similar brecciated rock masses is denuded, as the belt above described on the Montezuma property, but the rock is here fresh, undecayed and much harder; the color of the cement mass is greenish gray, instead of liver-colored; the laminated structure of the cement mass is very distinct.

Some distance further, in the bed of a creek which comes down from the Huron mine stamp mills, by the late disaster of the rupture of the dam of the reservoir of the stamp mill, the soil and rubbish were swept off clean from the bottom of this ravine, which offers at present a splendid opportunity to observe the irregular interposition of amygdaloidal breccia seams between compact masses of diabase. Both the diabase and the amygdaloidal seams sometimes intermingle, by interposition of wedgelike fragmental masses of one kind between the other. The amygdaloid breccia here 1ms not the appearance of being- the upper, foamy portion of any of the exposed diabase overflows, but is a shattered mass of a dark iron-colored, indurated mud, inclosing boulders of amygdaloidal and epidotic rock, and recemented by a network of seams filled with laumonite, more rarely with calcspar. The sedimentary origin of these belts of breccia is positively proved by the interlanimation of regular sandstone beds between the brecciated rock seams. Most of the amygdules of the boulders in the breccia are also replenished by laumonite.

Among the diabase layers some have an amygdaloidal structure and the rather large cavities in them are replenished with the green, soft magnesian mineral, amorphous, steatite-like generally, but sometimes mingled with radiated concretionary nodules of delessite.

Between the creek and the Atlantic stamp mills, in four or five different places exploratory work has been done in belts of amygdaloid, interposed from time to time between rather coarsely crystalline diabase belts, but they were not high enough in copper to continue the mining.

Several conglomerate belts are also exposed within this space, of which the one next to the brewery is the largest. They all consist of mostly quartzless, red colored porphyry pebbles, some of the size of a man's head; part of them are a compact crypto-crystalline felsitic mass, others are, perfectly composed of red feldspar crystals with scaly masses of a dark green mineral scattered between, which under the microscope-proves to be more or less altered hornblende. Less common in the accumulation of pebbles are such of a fine-grained dark diabase, in whose groundmass large crystals of red feldspar are segregated; also coarsely crystalline masses of olivine-bearing and hornblende-bearing gabbro are found among them.

The Atlantic mine, situated about one mile south of its stamp works, is opened in a large dark brown colored amygdaloid belt, overlain by a conglomerate belt fifty feet wide. This amygdaloid belt has in part the character of a breccia, composed of irregular larger and smaller blocks and rounded masses of a brown colored amygdaloid full of cavities, filled principally with calcspar and laumonite, but also quartz, prehnite, delessite, epidote and copper take part as filling-materials, either one alone or several of them associated, and of a cementing groundmass of the same brownish color as the inclosed amygdaloid masses, which exhibits distinct sedimentary lamination. The surface of the inclosed rounded masses of the amygdaloid is sometimes coated with a polished crust, streaky like slickensides; other times their pitted surface is shining as if glazed by exposure to fire.

The copper is quite unequally distributed in this rock belt; the richer portions of it are copiously interspersed with larger shotlike grains and also with branching hackly masses of the metal which have moulded themselves after the shape of pre-existing fissures and cavities in the rock; much of copper is also contained in the amygdules in association with the other mentioned minerals.

Other portions of the belt are poor and the copper contained in them occurs in smaller molecules. Practically no selection is attempted of the poorer rock from the richer, the entire width of the rock seam is taken out and the material run through the stamp mill, where as an average result three-fourths of a per cent of the rock mass is obtained in metallic copper. The working capacity of the stamp mill is so large that this small yield of metal still leaves a profit to the company.

The dip of the strata in the Atlantic mine is 55 degrees to the northwest. A large calcspar vein intersects the amygdaloid belt in the mine, diagonally, which generally is not metalliferous, but occasionally on crossing's with' the amygdaloid, nests and pockets of metallic copper and of silver were enclosed by the spar.

I have yet to remark that the amygdaloidal cavities of the rock fragments in the breccia adjoining the interstitial cement are usually filled with this sedimentary substance, in proof that the cavities of the amygdaloid at the time of the inclosure of their fragments were empty. In the amygdaloidal rock instead of rounded secluded cavities, often also long cylindrical, somewhat strumose channels occur, many of them aggregated in parallelism and replenished with delessite, in the radiated crystalline, or in the amorphous steatite-like condition. Similar parallel tubular-amygdaloidal cavities often occur also in other localities.

West of the Atlantic mine a few more succeeding diabasic belts show themselves in outcrops on the rolling drift-covered plateau land, but these are the last known to occur in this direction; all the rock exposures from here to the west shore of Keweenaw Point are sandrocks or conglomerates, and even these are generally hidden under drift masses.

At the base of the hills west of the Atlantic stamp mills a large series of sandrock ledges, interlaminated with conglomeratic seams presents itself, dipping under an angle of about thirty degrees to the northwest; locally also a dip to the southwest is observable.

The lower, very coarse-grained sandrock beds have a brick-red color, as they consist prevailingly of red orthoclase grains with only a small proportion of quartz grains.

The higher strata are brownish gray micaceous, middling fine-grained sandstones in thinly laminated even flags; they amount to very great thickness. This upper series is best exposed in the valley of the creek running through the north part of Sec. 33. Farther on, along Portage Lake, no more exposures are observable on this side, but on the opposite side of the lake, in Secs. 27 and 28, and along Swede Creek in Sec. 22, this same series of sandrocks is extensively exposed, which localities I shall describe below, in connection with the strata of the Hancock side.

Among the twenty-two conglomerate belts, observed between the east end of the Isle Royale property and the Atlantic mine, in some of them a small impregnation with copper has been observed, but not enough to be of any practical value for the miner. But loose blocks of conglomerate have been found mingled with the boulder drift, equally rich in copper with the best rock of the Calumet mines. Whether these are carried from the north or whether these are parts of a conglomerate belt hidden under the drift in the vicinity has not been ascertained. Southwest of Houghton, on the east slope of the so called "Six-Mile" hill, by recent explorations, conducted under the supervision of Capt., Ryan of the Hancock mine, an amygdaloid belt, richly charged with mass copper, has been discovered and been traced for a length of 800 feet in undiminished richness. The copper is principally inclosed within sparry and epidotic fissure seams intersecting the amygdaloid belt in a network of branches; besides the small masses of copper, from a pound to more than a hundred pounds in weight, the seams contain also a considerable amount of chalcocite. The amygdaloidal rock itself contains only little copper; it is of brownish lilac color, quite hard and compact; the contents of its cavities are calcspar, prehnite and datolite. In the upper portion of the belt, about seven feet in width, the most of the copper occurs, but also lower down, within a space of 36 feet, enough copper is disseminated to be worth mining. The hanging of the amygdaloid is a reddish brown, compact diabase. Short distance south of the pits a conglomerate belt occurs. The shaft sunk in the mining locality was at the time of my visit ninety-five feet deep, and on both sides of it drifts are opened for the length of about twenty feet; then the work was suspended, as it was only calculated to show the value of the deposit, to bring the property into the market. The relative position of this ore belt is calculated to be about 1,000 feet east of the Isle Royale belt. From Ryan's mine, which is already on the southern side of the Copper Range, onward to Rockland, a great many old mining locations are found, many of them since years abandoned, others still working; these will be considered subsequently in connection with the description of the geological structure of the Ontonagon district.

3. NORTH SIDE OF PORTAGE LAKE.

On the north side of Portage Lake, opposite Houghton, the greatest part of the surface of the steep hillsides, rising to an elevation of 500 feet above the level of the lake, is deeply covered with drift deposits. Only few cliffs of rock present themselves at distances. The information we have of the succession of rock beds on that side is principally obtained from mines and mining explorations; some parts of the succession are therefore not so well known as would be desirable.

Commencing again, to examine from east to west, as we did on the opposite side, we find, of the part of the series composing the east half of the Isle Royale property, nothing disclosed owing to the above mentioned heavy drift accumulations spread over the surface, and for the want of exploring pits in that part.

In the supposed continuation of the epidotic amygdaloid belt of the Isle Royale mine we find the first foothold for comparison of the north side with the south side of the valley of the lake arm.

The Douglass mine, the Concord mine and the Arcadian mine have been working in this belt on top of the plateau lands some distance off from the brow of the hills, but since many years the places have been abandoned. The amygdaloid in these mines is associated with compact and porous epidotic rock masses as in the Isle Royale mine, which are principally the repository for the copper in coarse hackly masses, also considerable amount of quartz and calcspar makes part of the metalliferous seams; peculiar to these mines is the large amount of flesh-red orthoclase, replenishing not only fissures in the rock masses, but it likewise constitutes the filling material of the amygdules associated with the chlorite or delessite.

West or northwest of this rock belt for the distance of nearly a mile, no connected cross-section is observable. By test-pits the occurrence of four different conglomerate belts has been ascertained between the Douglass mine and the Pewabic mines. One of these conglomerate belts is exposed on the plateau a few hundred steps east of the tramway from the Franklin mine to its stamp mill. A second one, known as the North Star conglomerate, is denuded in test-pits of the North Star Mining Company, near the quarter-post, between Secs. 18 and 19, T. 55, R. 33. The third belt is laid open in trenches dug by the Pewabic Company, about 900 feet east of the shafts of the mine, which received the name of Houghton conglomerate, and 400 feet farther west a fourth conglomerate belt occurs, believed to be a continuation of the belt mined at the Albany and Boston location. This belt is connected by a drift with the Pewabic mine, where from the seventy-fathom level of one of the main shafts a cross-cut has been made to the conglomerate belt.

The strata intersected by this drift are alternating seams of compact and amygdaloidal diabase.

None of the mentioned four conglomerate belts exceeds the width of from thirty to forty feet; they carry a small amount of copper, but not enough to be worth mining. The Franklin mine, Quincy mine and Pewabic mine are all opened in the same rock belt. Part of the copper is found disseminated through the mass of a brownish dark colored amygdaloid belt, the upper portion of which is the richest. Seven or eight feet next to the massive diabase belt in the hanging are taken out, which, going through the stamps, furnish about two per cent of washed metal.

A large additional quantity of copper in these mines is obtained in heavy masses, often many tons in weight, which are deposited into crevices of the amygdaloidal belt in association with calc-spar, epidote, quartz, prehnite, laumonite and sometimes with porcelain-like datolite masses. The copper rarely occurs in well formed crystals of its own form; it has generally shaped itself after the interstices left between the other minerals inclosing it, or it moulded itself into the form of one of these, which happened to be removed by lixiviation. The dip of the strata in the Quincy mine and the others adjoining it, varies between fifty and fifty-five degrees to the northwest. The hanging of these mines is formed by a wide belt of a dark colored compact, middling coarsely crystalline diabase. Under the microscope its components are found to be turbid plagioclase crystals, in intermixture with brownish colored augite, and an abundance of olivine grains in clusters, associated with magnetite, which latter, by higher oxidation and infiltration into the neighboring parts, tinges them purplish. Besides there are plenty of pseudo-amygdules composed of an amorphous grass-green magnesian mineral, in which often radiated chlorite concretions are segregated.

In portions of this diabase belt, part of the feldspar constituent seems to be orthoclase of brick-red color, but not always these red colored crystals are orthoclase, as sometimes a dim polysynthetic striation is observable in them.

The amygdaloid of the Quincy mine has like most other amygdaloids a minutely crystalline structure, similar to the ashbed diabases, in which the augite is rarely seen in transparent crystals, but constitutes a turbid interstitial mass full of magnetite granules, in which colorless acicular plagioclase crystals are copiously dispersed. The magnetite is to great extent altered into sesqui-oxide, which tinges the rock reddish brown. The majority of the diabase belts occurring in the cross-section from the Isle Royale property to the Atlantic mine are olivine-bearing and many of the belts are lustre-mottled.

The lustre-mottled diabase associated with the Mabbs vein on the Isle Royale property is particularly rich in olivine; the same is the case with the diabase belt in the hanging of the Isle Royale vein.

The wide diabase belt exposed near the bridge at Hough ton is likewise olivine-bearing, also the coarse-grained diabase in the mining pits on the Southside property, which is supposed to be the counterpart of the rock belt in the hanging of the Quincy mine, and a great many others, which seems to prove that olivine-free diabases are in the Portage Lake region not the prevailing type, as has been supposed by some.

About 1,000 feet west of the Quincy mine, another amygdaloid belt is worked for copper in the Hancock mine. The amygdaloid is dark brown, earthy-looking; its cavities are principally filled with delessite, laumonite and calcspar. The rock belt is much broken up and recemented into a breccia, which is intersected by a network of fissure seams filled with calcspar, prehnite, laumonite, in association with copper.

West of the shaft, exploring trenches have been dug across the property to its boundary lines, in which an alternation of compact and amygdaloidal diabases is laid open, besides two interstratified conglomerate belts and sandstone layers. A third conglomerate belt much wider than the two former, crops out a short distance farther west, then succeeds a large belt of amygdaloidal rock with unusually large irregulars-shaped anastomosing cavities filled with chalcedonic and crystalline quartz with porcelain-like datolite and delessite. This belt is much shattered and recemented into a breccia by quartz and spar seams; it contains not enough copper to be of practical value. The three mentioned conglomerate belts are likewise cupriferous, but the amount contained is small.

The Atlantic mine and the Hancock mine are supposed to be opened in the continuation of one and the same rock belt, and a farther current supposition is, the identity of this belt with the so called Ashbed in the Eagle River district.

There is much similarity in the lithological character of the compared rock belts, but several other amygdaloids occupying different horizons resemble them as much; it requires, therefore, further proof to establish their identity.

On the west side of the above described amygdaloid, well exposed on the track of the Calumet R. R., a few more outcrops of diabasic rock belts are noticeable, but as in that direction no mining pits are opened and deep drift deposits are spread over the surface, I am ignorant of the succession of strata for an interval of not quite half a mile, when again exposures are found on the east line of Sec. 28, T. 55, R. 34. The first beds seen are very coarse-grained sandrocks of red color interstratified with seams of conglomerate; they consist principally of large grains of red feldspar and of a much smaller proportion of quartz grains and water-worn granules of diabase. Strike of the beds north-northeast; their dip northwest under an angle of thirty degrees. Next succeeding this large belt are fine-grained, gray colored, micaceous sandstones, splitting in thin, even flags, which lawyers are exposed in a belt a quarter of a mile wide, and retain, with little variation, the same character from one end of the section to the other. In the bed of Swede Creek the upper part of this succession of sandrock beds is finely exposed; west of this ravine all the land is covered with drift and nothing is known of the underlying beds between here and the western Portage Canal entry. This belt of gray, micaceous sandstones, is supposed to be an analogon of the group of arenaceous beds largely displayed in the Ontonagon district, and known under the name of Nonesuch mine rock series. It has been traced from Portage Lake northward to the Mouth of Hill's Creek. East of it occur in this part two very large conglomerate belts, one of them over a mile in width, which, if continued south to the Portage Lake region, must have very much attenuated, as the largest conglomerate belt seen there is not much over one hundred feet in width.

4. NORTHERN PART OF KEWEENAW POINT.

Proceeding to describe the structure of more northern parts of Keweenaw Peninsula, I take as starting point the west side of Torch Lake, following the courses of Hungarian Creek and Douglass Houghton Creek, in both of which creek-beds we ascend over a large succession of horizontal Silurian sandstones, until near the summit of the ravines we see them unconformably abut against the upheaved strata of the Keweenaw rock series.

This fact has been contradicted by Dr. M. E. Wadsworth, who pretends to have observed in these localities a conformity of the Silurian sandrocks with the Keweenaw rocks, whereby the latter would occupy the highest position and the Silurian sandstones be the underlying older strata. Ascending the narrow ravine through which Hungarian Creek comes down the hillside, forming on its way several cascades, we step over horizontal ledges of a red sandrock identical with the horizontal sandstone ledges exposed along the shore of L'Anse Bay, etc., until vertical rock walls nearly 100 feet high obstruct our progress. The creek leaps over them into the abyss. These high walls are formed of a large succession of horizontal beds of sandstone very similar to the ledges forming the bottom of the creek-bed below. Climbing to the top of the walls by a circuit and following the creek upward, we see the horizontal beds continue for some distance and find them to form several other abrupt offsets, causing cascades from fifteen to twenty feet in height; finally, near the summit of the hill, we observe another cascade about twenty-five feet high, caused by the projection of a conglomerate belt and an underlying belt of amygdaloidal rock, both of which are dipping northwest under an angle of about forty-five degrees, and right under the falls the horizontal ledges of sandrock, which constantly had been under our feet up to this place, are seen in direct contiguity with the upheaved amygdaloid ledges. The sides of the creek-bed are covered with loose rubbish and the contact is not visible there, but in the bottom of the shallow stream the unconformity of the sandrock ledges with the trappean rock belt is so fairly exposed that no misapprehension is possible. The sandstones, instead of dipping under the amygaloid, as Dr. Wadsworth thinks, have, if they are not altogether horizontal, rather a slight inclination in an opposite direction, away from the hill, and not toward it. The sandrock ledges forming the contact differ from Keweenawan sandrocks by an almost purely quartzose composition and a light color, white and red blotched.

At Douglass Houghton Falls the same relations between the Silurian and Keweenawan rocks exist.

Coming from the plateau on top of the hills, we see on it a large succession of compact and amygdaloid diabase belts intersected by the bed of the creek, which then at once tumbles over a precipice formed of an additional series of diabasic rocks near 100 feet in height; the dip of these beds is about forty degrees to the northwest.

Beneath this escarpment, a large body of amygdaloidal rocks in a much shattered condition, recemented into a breccia by sedimentary material, forms the bed of the creek. At the base of the rock bluffs forming the falls, a fissure vein is exposed which is filled with calcspar, prehnite, quartz, datolite, and carries some copper. A small drift following the vein for about thirty feet informs us that years ago miners tested their good fortune here and found themselves disappointed.

The brecciated soft and disintegrating amygdaloid mass forms the river bed for a short distance below the falls, then succeeds a large series of alternating beds of sandstones and conglomerates, which dip in the same northwest direction as the trap rock at the falls, and about under the same angle. These sandstones and conglomerates are in part very soft and friable; they are in part light whitish colored, composed almost exclusively of quartz grains and resemble the eastern horizontal sandstones. Other sandstone beds in the alternation are hard, dark reddish brown colored, and contain besides quartz granules also feldspathic grains and trappean detritus. The conglomerate seams are in part formed of densely crowded trappean, amygdaloidal, and porphyritic pebbles with sparingly interposed arenaceous cement; other times the main mass of such conglomerate is formed of a quartzose sandrock with kaolinitic cement, in which pebbles are quite distantly scattered. The narrow belt of diabase, which, according to Dr. Wadsworth's statements, is found interlaminated with this group of sandstone and conglomerate beds, I was unable to discover, although I took special pains to find it.

Descending the creek, this very large succession of northwest-dipping arenaceous and conglomerate beds is seen for quite a long space, well exposed in the steep sides of the ravine, but then the layers begin to be broken up into an irregular mass of rubbish, pebbles, sandstone blocks and loose sand masses, intermingled without stratified arrangement.

After short interruption of the exposures of an orderly succession of beds, we observe, descending with the stream, first, in the bottom of the creek, light colored red and white blotched horizontal sandstone ledges, which soon, in the further descent, are seen to crop out in the sides of the ravine, and thence all the lower part of the hillside is formed of these horizontal layers, which, if not perfectly horizontal, instead of dipping forward to the hillside, gently dip away from it.

A gradual decrease of the dip as we descend the creek from the falls, which occurs according to Dr. Wadsworth's assertions, is not perceptible. The inclination of the northwest-dipping sandrock strata remains the same as far as they are exposed, then conies the girdle of loose rubbish, and the next appearing stratified rock ledges are at once in a horizontal position; the change is abrupt and the slight deviation of the beds below from horizontality is not in the direction of the beds above, but opposite,—anticlinal to them.

Relying on the northwest dip of the strata below the falls, I concluded they were lower sedimentary beds, belonging to the Keweenaw group, and was confirmed in this opinion by finding a short distance lower down the hillside, the horizontal sandstones in all regularity displayed. Considering only the lithological character of the northwest-dipping strata at the falls, I would not have hestitated a moment to identify them with the Silurian eastern sandstones, which, according to recent investigations of Prof. Irving, they actually are. The special explanation of this abnormal position of the eastern sandstones in the immediate proximity of the older Keweenaw rocks, and the undisturbed condition of the beds some distance off from the contact, will be found in his own forthcoming report.

Similar irregularities in the position of the Silurian sandstone beds in the immediate vicinity of older upheaved rocks are recorded in the third volume of the Wisconsin reports.

This seems to prove that in the Lake Superior region, after the general disturbing forces had subsided, still in circumscribed smaller areas dislocations of the strata occurred. An instance of this kind presents itself fairly displayed for observation on the north shore of Bête Grise Bay, where we can see in various spots the steeply upheaved, northward-dipping rocks of the Keweenaw group in discordant contact with Silurian sandrocks, which latter in some places abut against the former in horizontal position, but more frequently we find them dipping southward, away from the trappean rocks, under an angle from thirty to forty degrees, while off from the contact line, on the shallow bottom of the lake, the dip of the strata becomes much flatter, and on the south shore of the bay their position has become perfectly horizontal. A detailed account of the rock outcrops along the shore of Bête Grise Bay will be given below in connection with the description of the Bohemian Range.

The horizontal Silurian sandstones are well exposed in a quarry on top of the incline of the railroad to the Calumet stamp mills; their position is not perfectly horizontal, but undisturbed sedimentary beds very frequently are not completely horizontal. Their contact with Keweenawan rocks is not visible. The first outcrops of these are noticeable about one-half a mile west of the quarry, where a large belt of quartz-porphyry is exposed by a cut of the railroad; it dips in steep inclination to the northwest. This quartz-porphyry is perfectly similar to the quartz-porphyry pebbles which compose the Calumet conglomerate. It is the only locality known to me on Keweenaw Point, where such a rock belt occurs; the porphyries of the Bohemian range are not of the quartziferous kind. Judging from its topographical position with regard to the Douglass Houghton Falls, this porphyry belt must belong to a lower horizon than the beds there.

Following the Calumet road from this place northwestward across the strike of the formation, we have, excepting the rock exposures in the creek above the Douglass Houghton Falls, no occasion to observe a larger connected cross-cut, until approaching the Osceola mine, which is working an amygdaloid belt about 800 feet east of the Calumet conglomerate belt.

Here, by the work of the different mines, we are well informed of the order in the succession of rock beds; the Calumet mines made, as above stated, a cross-cut 2,468 feet long, showing the rock series south of the Calumet conglomerate belt, and by the Tamarack shaft other 2,000 feet of strata north of this belt will be disclosed within a short time.

This belt, about a mile in width, is the horizon within which most of the productive copper mines of Keweenaw point are situated. Several of the rock belts are recognizable by certain lithological characters and are found to be persistent for long distances, therefore can serve as excellent guides of the miner in his calculations where to meet with a rock seam he is desirous to find.

One of the most persistent beds is the so called Allouez conglomerate, which is traceable almost without interruption, from Portage Lake to the north end of the Keweenaw Peninsula. Its calculated vertical distance above the Calumet conglomerate is between 1,300 and 1,400 feet, measured from the Allouez mine southeastward; which distance of course is liable to vary considerably in different localities, as some beds shrink or widen and others become entirely eliminated or new seams are interposed. The Allouez conglomerate is never a very wide belt; forty feet is about its maximum thickness; often it is contracted to a narrow seam not one foot wide; locally it is richly impregnated with metallic copper, but in the greater part of its longitudinal extension the belt is barren of the metal, or at any rate, too poor to be profitably mined.

The conglomerate belt about 500 feet east of the Pewabic mine amygdaloid is considered to represent the Allouez conglomerate; from the Pewabic mine this belt is traceable without interruption through the Franklin, Mesnard, Dorchester and St. Mary's mining properties to the Albany and Boston mine, presently named Peninsula mine. On all these mentioned places, long time abandoned except the Peninsula mine, extensive cross-cuts had once laid open the succession of beds, particularly on the St. Mary's property. At present all these ditches and pits have caved in and are filled with soil and debris; for the detailed descriptions of these cross-sections I therefore have to refer the reader to Prof. Pumpelly's report and maps, who had a chance to examine the exploring trenches when they were freshly opened, and could make use of the notes of the parties who did the work.

The first mining on the Albany and Boston location was done in the amygdaloid belt about 100 feet above the presently worked conglomerate belt. This amygdaloid is much broken up and recemented into a breccia by seams of calcspar, laumonite, prehnite and quartz; the same minerals are also the filling-material of the amygdaloidal cavities, besides epidote, delessite, analcite, orthoclase and copper. In the upper levels it was found to be very rich in the metal, but going deeper the copper lessened so much that work had to be abandoned.

The conglomerate belt mined at present has a width from fifteen to twenty feet; its pebbles are rather coarse; they consist principally of quartz-free porphyry of dark, reddish brown color, either with a compact, crypto-crystalline groundmass, or have a granite-like structure consisting of agglomerated red feldspar crystals with sparingly interspersed clusters of chlorite scales, associated with epidote. The copper is somewhat unequally distributed in the rock belt; the mined rock is therefore picked over before going to the stamp mills; still the amount rejected is not very large.

Four hundred and seventy-five feet northwest of this conglomerate a shaft has been sunk into an amygdaloid belt which is supposed to be the continuation of the copper-bearing rock seam of the Pewabic mine or Franklin and Quincy mines. It is locally well impregnated with copper, but for some reasons the mining of this belt has been suspended for several years.

In association with this amygdaloid occurs a very peculiar rock seam of porphyritic structure, which is impregnated with copper. There are two modifications: one is well laminated banded rock, resembling at a distance a coarse-grained sandrock intensely red colored, with alternating lighter and darker seams, the ledge amounting to about two feet in thickness; the other is massive, deceivingly similar to a compact brown amygdaloid with densely crowded amygdules, but upon closer inspection the supposed amygdules are clusters of crystals with sharp ends, to which the inclosing groundmass has adapted itself; often also a granular mixture of quartz, epidote, copper has partially or entirely replaced and moulded itself into the spaces formerly occupied by these crystals.

The dark, liver-colored, fine-grained groundmass of the rock, exhibiting a resinous lustre on fractures, consists mainly of a colorless quarts mass with copiously imbedded, laterally coherent, more or less minute crystalline molecules, intensely red colored by hematite, which seem to be feldspar. The laminated variety of this rock consists of the same dark, liver-colored groundmass disposed in layers of various thickness with interposed sheets of lighter red color, and the layers themselves are full of small crystals, originally feldspar but changed by paramorphosis into laumonite. The analogy of this porphyritic rock with the porphyries of the Bohemian Range is obvious, as the matrix of both is identical in material and many of their structural features perfectly agree. The strata exposed on the south shore of Keweenaw Point, in T. 58, R. 27, Sec. 30, especielly deserve to be mentioned as similar in structure to the laminated form of the rock at the Albany and Boston locality.

On the Albany and Boston property is, 400 feet east of the productive conglomerate belt, another conglomerate denuded by trenches, which corresponds with the Houghton conglomerate found in the Pewabic mine location; it does not carry enough copper to be of value to the miner.

The next locality north of the Albany and Boston mine where actual work is done, is the Osceola mine in T. 56, R. 33, Sec. 26, N. W. ¼, which, as I have above stated, is opened in an amygdaloid belt about 800 feet east of the Calumet conglomerate, and, as the supposition is, over 2,000 feet stratigraphically below the Albany and Boston conglomerate belt, which is believed to be the same as the Allouez mine conglomerate, although a continuity has not been actually traced.

The Osceola amygdaloid belt is about thirty-five feet wide; it dips in conformity with the other strata under an angle of forty degrees to the northwest; its color is reddish brown, dull, earthy; part of it is soft, porous, other parts hard, compact; its amygdules are principally filled with calcspar, delessite, prehnite and epidote; sometimes also with quartz, datolite, etc. The copper in the rock is most found in a network of fissure seams traversing the amygdaloid belt in association with calcspar, prehnite, datolite, quartz and epidote, filling the interstices between these minerals in hackly masses of smaller or larger size; sometimes the copper is found in druse cavities in very perfect, but rather small crystals; the spar crystals of such druses usually are bright red colored, being penetrated with an abundance of minute scales of copper.

The datolite, which in the Portage Lake mines occurs only in amorphous porcelain-like concretionary masses, is here found in large crystals of pale greenish milky color, but rarely obtainable with free ends, as the crystals are densely agglomerated and enveloped with calcspar and prehnite.

The hanging of the Osceola is a dark blackish colored, fine-grained diabase, which incloses in its linear fissures sheets of copper, and is locally throughout its entire mass impregnated with minute scales of copper. Thin sections exhibit a large proportion of olivine grains in its composition, besides the ordinary constituents, plagioclase, augite, magnetite and interstitial masses of the green chlorite or serpentine-like mineral, which likewise fills distant globular amygdules.

Some years ago, on the Osceola location, also the Calumet conglomerate belt was successfully mined, but the mine caved in and had to be abandoned. The work in this belt was not resumed, because the conglomerate in its southwestern extension on the property contracted and became almost barren of copper. On the adjoining Tecumseh location, where also a few shafts were sunk on the continuation of this belt, it was still found more contracted and contained little or no copper. Farther to the southwest this belt seems to be missing altogether.

In the hanging of the conglomerate belt at the Osceola location, a dark, fine-grained compact diabase belt occurs, which incloses irregular amygdaloidal rock masses rich in copper, most of it in coarser lumps,—so called barrel work. They use the old shaft in the conglomerate belt to come to this rock belt and work it to advantage.

The compact and the amygdaloidal rock are both olivine-bearing; the copper is principally found in fissure seams, associated with calcspar, prehnite and dark red orthoclase.

Under the superintendence of Capt. Daniell of the Osceola mine, the above mentioned deep shaft of the Tamarack location has been commenced in 1882 and has in the remarkably short time, up to July, 1884, reached a vertical depth of 1,550 feet. A mapped record of the different strata sunk through in the shaft, which I received by the kindness of Capt. Daniell, is appended to this report,* to which I will add some descriptive remarks, concerning- the lithological characters of the more important beds of this series. The shaft is located near the S. E. corner of the S. W. ¼ of the S. W. ¼ of Sec. 14, T. 56, R. 33; it first went through fifty feet of drift masses, then conies a belt of blackish colored compact diabase, fifty feet in thickness, beneath it a much narrower amygdaloidal seam, then another compact diabase belt, seventy-five feet wide, and again an amygdaloidal belt follows, and so alternately to a vertical depth of 460 feet, at which six belts of diabase and five of amygdaloid had been sunk through. Several of these amygdaloid belts were found well impregnated with copper.

*[In place of the above record I have substituted geological columns of the North Tamarack shafts, Nos. 3 and 4, complete to Jan. 1st, 1894. These records are due to the courtesy of Capt. Daniell, and of Prof. R. M. Edwards, the Mining Engineer of the Tamarack company.—L. L. HUBBARD.]

At 460 feet from the surface a thin belt, only two or three feet wide, of a brownish red, very fine-grained jaspery rock occurs, which likewise carries copper. It resembles in its substance the homogeneous fine-grained pebbles of the conglomerates of the Keweenaw group. The very brittle rock is permeated in all directions by linear fissure seams filled with laumonite and calcspar or copper. Immediately beneath this belt succeeds a brecciated rock belt, forty feet thick, composed of dark brown colored, half decomposed earthy looking fragmental masses of partly compact diabase, cemented by an abundance of calcspar and laumonite seams, which are remarkably rich in copper interwoven with the sparry crystal aggregate, or also in heavy masses, many pounds in weight, imbedded between them. The foot wall of this cupriferous rock stratum is formed by a dark blackish colored fine-grained diabase belt, 170 feet thick, in its oblique intersection, which by its jointed structure, on exposure or by the stroke of a hammer, falls into small irregular sharp- edged pieces, the surfaces of which are covered with a smooth shining slickenside coating, consisting of a dark green, semi-transparent, soft, lubricous, delessite-like mineral and intermediate between these slickenside rock joints most generally a thin sheet of copper is found deposited, varying in thickness from that of the artificial leaf gold to sheets one-eighth of an inch and more in thickness. The amount of copper found in this rock is larger than I have seen it in any other compact diabase rock. Under similar circumstances sheets of copper occur in the diabase forming the hanging of the Osceola amygdaloid, and in that in the hanging of the Calumet conglomerate belt. At the vertical depth of 670 feet, the shaft strikes a conglomerate belt from three to four feet in thickness, which is supposed to be the equivalent of the Allouez conglomerate; it is well impregnated with copper in coarse hackly masses, its porphyritic pebbles are soft, decomposing, and the interstitial cement is calcspar, in intermixture with chloritic mineral and laumonite; parts of the belt are also formed of a fine-grained, laminated sedimentary mud mass of deep reddish brown color, variegated by intermingled greenish colored streaks. The next lower 200 feet are almost entirely of amygdaloidal character, with a few interposed narrow seams of compact diabase. They are comparatively poor in copper. A portion of the amygdaloidal rocks is very hard, with a sort of vitreous fracture; another portion is soft and in progress of decomposition. The amygdules are mainly replenished with calcspar, laumonite, delessite and some quartz.

From the depth of 900 feet to 1,330, four rather large, compact belts of diabase alternate with three narrower amygdaloidal belts, the lowest of which is of a brecciated structure. At the depth of 1,341 to 1,357 follows an amygdaloid belt, from there to 1,409 compact diabase, then amygdaloid to 1,424, which latter carries copper and is partly a dark purplish colored earthy-looking conglomeratic mass, intersected by spar and laumonite seams, partly a very compact dark gray colored rock, with calcspar and epidote amygdules, some of it shattered and firmly recemented into a breccia by epidotic seams. From 1,424 to 1,495 compact diabase, then 15 feet of amygdaloid and from 1,510 to 1,550 a fine-grained reddish brown colored compact diabase, which was the bottom rock of the shaft on the 10th of July, 1884. Nearly all the different compact diabase belts occurring in the shaft, in thin sections exhibit a lustre-mottled structure; the light colored areas are almost exclusively composed of transparent plagioclase crystals, intermingled with pale yellowish brown very fresh augite; in the surrounding dark colored, interstitial area, very little augite is found associated with the plagioclase, but instead of it abundant clusters of a red colored, micaceous mineral (rubellan?) associated with agglomerations of magnetite granules and with grains of olivine, of which latter the delicately laminated, micaceous mineral seems to be a paramorphic product. The red color does not seem to be essential to it, as portions showing the same laminated structure are almost colorless. Seen vertical to the cleavage, they are not dichroic, but distinctly so if the light enters parallel to it. In all of them, numerous pseudo-amygdaloidal interstitial spaces are replenished with the often before mentioned amorphous or radiated crystalline steatite-like mineral of pale or darker green color.

Another similarly interesting exploring work has been shortly finished by the Calumet and Heel a Company. In order to learn the succession of rock beds on their location, southeast of the conglomerate belt, they ran a drift from the ninth level of shaft No. 4, of the Hecla mine, beginning at the foot-wall of the conglomerate, and carried it at a right angle to the strike of the formation to the limits of their property, a distance of 2,463 feet.

Mr. Wright, the agent of the mine, had the kindness to furnish me with a copy of the mapped record of this drift, which is appended below.*

[*Through the courtesy of the present management, I am able to append a new copy that shows several sections in different parts of the mine not opened up at the time the above was written.—L. L. HUBBARD.]

We observe on it the intersection of ten different amygdaloid belts, with intervening much wider belts of compact diabase. At the distance of 1,571 feet from the Calumet conglomerate, another conglomerate belt, 44 feet wide, is intersected, which has been identified as the prolongation of the conglomerate belt on the Kearsarge mining property, which, on the Ahmeek location has been mined for copper, but has been abandoned again, the copper being too unequally distributed through it. Locally, the belt was found to be quite rich.

Several of the amygdaloid belts, intersected by the drift, were found sufficiently cupriferous to be worth mining, but for the present no effort was made to do any work in them, as the conglomerate belt gives sufficient employment for all their laborers. Among these the fourth belt from the conglomerate, the so called Osceola amygdaloid, is the most promising. The conglomerate belt of the Calumet and Hecla mine averages a width from 12 to 25 feet; its dip varies from 36 to 39 degrees to the northwest. Fully two miles of the length of the belt are on this mining property; the deepest shafts following the inclination of the belt are 2,700 feet long, which makes a vertical depth of about 2,068 feet below the surface. On the entire extension of the property, the conglomerate belt has very few barren spots, and the rock is, without selection, sent to the stamp mills where it yields about five per cent of washed metal; portions of the rock are much richer, as high as thirty per cent in metal. The product of the mines during the last three or four years was about 16,000 tons of ingot copper annually.

The conglomerate of this belt is reddish brown colored, hard and compact; locally composed of rather large, rounded pebbles, but the main mass consists of smaller pebbles with many little-worn, angular rock fragments among them. The interstitial material consists of smaller arenaceous particles held together by siliceous and calcareous cement; the copper in the rock occupies mainly these interstitial spaces between the pebbles, and is sometimes replacing the cement altogether.

The union of these fragmental masses is very firm, a stroke of a hammer does not sever their connection, but breaks the mass straight across the pebbles, which, with the exception of a small proportion of diabasic and amygdaloidal boulders are all of porphyritic nature but quite variable in molecular structure. A large portion of them consists of a reddish brown, compact, homogeneous, silico-feldspathic substance, with smooth, conchoidal fracture. Others inclose within the same aphanitic groundmass well formed, larger crystals of feldspar, of red or whitish color; in still others, which are often more abundant than the others, the dark reddish colored, compact groundmass incloses, besides feldspar crystals, a great number of rounded transparent, colorless grains of quartz which, on fractures, give a blackish reflex. Other pebbles have none of the amorphous groundmass; they consist of a granite-like agglomeration of interwoven red feldspar crystals, with scarcely any other component, or else this same crystalline, feldspathic rock mass contains copiously interspersed quartz grains, besides scattered blackish colored molecules which sometimes are recognizable as altered hornblende crystals or as biotite scales, but often are a shapeless, earthy-looking remnant of a decomposed mineral, not to be determined. These rocks could, with propriety, be classed with granite, but they are allied with the before mentioned porphyries by transitory forms which are not completely crystalline, but have a scanty interstitial groundmass analogous to the groundmass of the porphyritic kind.

I have stated above that the copper occupies, in the conglomerate, the interstitial spaces between the pebbles and often takes the place of the previously existing arenaceous cement. Rarely the copper had a chance to enter the substance of the pebbles through capillary fissures imperceptible to the eyes before the pebble is fractured, but sometimes the same altering influences which removed the interstitial arenaceous material, replacing it by calcspar, epidote and copper, affected also the larger pebbles; they made them first porous and discolored and finally changed them into an epidotic mass permeated with a spongeous skeleton of copper in association with more or less calcspar. Such altered pebbles, some of them as large as a man's head, quite frequently occur at the Calumet mine, and also sometimes in the conglomerate of the Albany and Boston mine. In some instances the copper has almost entirely replaced the material of such pebbles and forms solid, ponderous masses in the shape of the pebble, other times the change was not perfect, and the spongeous copper skeleton inclosed within its cavities yet unaltered crystals of orthoclase and quartz grains enveloped by a mealy chloritic and epidotic crust.

Prof. Pumpelly first gave notice of the occurrence of such copper masses in pebble form and suggested their paramorphic origin by replacement of the material of the decomposing porphyry pebbles.

The conglomerate of the Calumet mines frequently incloses seams of a fine-grained, well laminated sandrock, exhibiting" ripple marks on the surface of its layers, and locally such beds are richly impregnated with copper. Like in all the sandrocks of the Keweenaw group, the feldspar grains overbalance the quartzose grains in the rock mass. The hanging of the Calumet conglomerate is a dark colored, fine-grained diabase, which, like the above mentioned diabase belt in the Tamarack shaft, 500 feet below the surface, has a jointed structure, with the cleavage seams coated over with a soft, chlorite-like mineral in slickenside fashion, holding between themselves sheets of copper from the thickness of tissue paper to that of a knife blade and sometimes six or eight inches square; likewise are cloudy patches in the solid mass of the diabase disseminated with an abundance of scaly molecules of copper, but the miner considers the amount of metal too small to pay any attention to its collection. In association with the compact diabase in the hanging, amygdaloidal rock masses occur, whose amygdules formed of calcspar, laumonite, quarts and delessite, often contain a considerable amount of copper.

I have previously mentioned that the Calumet conglomerate thins out and is almost destitute of copper in its extension south of the Osceola mine, and soon after entirely disappears. The same is the case in its extension northeast of the Calumet mine, on the Schoolcraft mining property, where extensive work has been done in this belt, but the large burrows of waste rock, in which no copper can be detected, show that the Calumet mine struck an extraordinary rich spot and that locally this belt is almost barren of the metal. The work in this conglomerate on the Schoolcraft mine is long time suspended, but on the Osceola amygdaloid belt, which likewise intersects the property, mining has been continued until late. Farther to the northeast the continuation of the Calumet conglomerate belt has been traced only for a short distance; it was found to be much narrower and poor in copper.

In the mines on the south side of the so called Greenstone Range, a cupriferous conglomerate belt, holding approximately the relative stratigraphical position of the Calumet conglomerate, has been identified with it, but it is not positively ascertained whether this is a continuation of the same belt or not. A half mile northeast of the Schoolcraft mine a new mine, called the Wolverine mine, has recently been opened in an amygdaloid belt, 2,865 feet east of the Calumet conglomerate, or 1,250 feet east of the Kearsarge conglomerate.* The location is on the N. ½ of the N. E. ¼ of Sec. 17, T. 56, R. 32.

[*Inasmuch as several changes of Dr. Rominger's figures had been made in the type-written copy of his manuscript, before the latter came into my hands, I take the liberty of inserting here several measurements made a number of years ago by Mr. James Crawford, and kindly furnished me by Fred Smith, Esq., agent of the Allouez mine, who vouches for their substantial accuracy. They are as follows, to wit: On the Kearsarge location,—

Allouez conglomerate to Calumet and Hecla conglomerate, 2,050 ft.
Calumet and Hecla conglomerate to Kearsarge conglomerate, 1,500 ft.
Kearsarge conglomerate to Kearsarge amygdaloid, 1,250 ft.

—L. L. HUBBARD.]

This belt is unusually rich in copper. It is a dark purplish brown rock, with dull earthy fracture, harder or softer, much shattered into fragments, which are recemented into seams of calcspar and of orthoclase in association with quarts, epidote and delessite. The amygdules are filled with laumonite, epidote, delessite and calcspar, usually several of them associated; in some parts of the rock the amygdules consist nearly all of a dark green amorphous serpentine-like mineral. Much of the amygdaloidal belt is transformed into a light green porous epidote rock, which principally carries the copper in ponderous hackly masses, so called barrel-copper. Near the surface the copper is much oxidized, coated over with red oxide, malachite and azurite. The same amygdaloid belt is laid open by numerous test-pits in the adjoining Kearsarge property.

The foot-wall of the amygdaloid is a coarsely crystalline, dark colored diabase belt, about 100 feet wide. It projects in a row of bluffs, at the base of which a belt of sandstone and conglomerate ledges crops out. The foundation of the stamp mill rests on this sandrock, which is probably the equivalent of the so called Kingston conglomerate. East of it are outcrops of compact diabase, but the natural exposures in that direction are much interrupted and no explorations of the ground had been made, by which the farther succession of underlying beds could be studied.

One mile north of the Wolverine mine is the Allouez mine, from which the often before mentioned Allouez conglomerate received its name.

Measurements made from the mine across the trend of the formation southeastward show the horizontal distance from the Allouez conglomerate to the Kearsarge conglomerate to be 3,810* feet, or reduced to vertical thickness of the intervening ledges 2,647 feet.

At the Allouez mine the strata dip under an angle of 37 degrees to the northwest. The thickness of the conglomerate, belt is from 20 to 25 feet; it resembles the Calumet conglomerate with regard to the nature of the pebbles composing it, but they are generally of larger sizes. The copper in the rock is unequally distributed, and much of it has to be rejected. The average yield of the rock sent to the stamp mills is not much over one per cent of washed metal.

[*Sec foot-note on preceding page.—L. L. H.]

Beneath the conglomerate various coarser and finer-grained compact diabase belts are well exposed on the mining property. The hanging of the belt is a blackish colored, very fine-grained rock; part of it is lustre-mottled; it consists of a mixture of clear, prismatic crystals of plagioclase with about an equal quantity of pale brownish transparent augite, besides a good proportion of olivine grains which superficially are altered into a turbid crypto-crystalline, greenish substance; the magnetite in the rock is partially altered into red oxide. This rock is the equivalent of the lustre-mottled rocks forming the base of the bluffs at the Cliff mine and along the entire extent of the Greenstone Range.

The succeeding higher strata at the Allouez mine do not project in so steep escarpements as at the Cliff mine, and further to the northeast they are also not exactly alike with them in lithological character, but in the conglomerate belt, which from here can be traced almost without interruption to the northeast end of Keweenaw Point, we have a sure index of the geological horizon.

The rock belts on the north side of the conglomerate are very well exposed. Above the dark, fine-grained, partly lustre-mottled rock in the hanging, which amounts to about 100 feet in thickness, an alternation of amygdaloidal seams with compact and pseudo-amygdaloidal diabase belts succeeds in a belt a half mile wide, almost without an interruption of the outcrops. The relation of the amygdaloidal portions to the compact portions of a belt is here finely disclosed; we observe here that the amygdaloidal belts are not separate overflows, but constitute merely the upper portion of the compact belts; often also the amygdaloidal masses are inter mingled with the compact rock in narrow bands and in lenticular masses wedging out at both ends; these bands and secluded lenses of amygdaloid are generally very hard, fine-grained, with a flinty fracture.

The northern strata have the fine-grained porphyritic structure of the so called Ashbed diabase; the Ashbed itself is not observable, as on the place where it should be expected the surface begins to be covered with drift. Short distance beyond this drift-covered space, at the location of the stamp mill, the large conglomerate belt is seen exposed, whose continuation at Eagle River is a mile in width, and probably would also here not be found narrower if it was better denuded.

A mile northeast of the Allouez mine the Kearsarge conglomerate has been worked for copper at the Ahmeek mine. The belt has here a thickness of 60 feet, consisting in part of well laminated fine-grained sandrock ledges, in part of conglomerate layers. These latter differ from other conglomerates of this group by the dark, blackish color of their cement and by the prevalence of sharp angular, rather small fragments, over the rounded water-worn pebbles, most of which are a dark brownish, red colored quartz-porphyry. Some portions of the rock are very rich in copper, but only in patches; the remainder of the belt is poor or contains no copper at all; the mining has therefore been discontinued.

The hanging of the conglomerate is a black colored, middling fine-grained diabase, consisting of transparent plagioclase and augite crystals, besides numerous clusters of olivine grains more or less altered and associated .with an aggregation of magnetite granules.

The foot-wall of the conglomerate is a coarsely crystalline pseudo-amygdaloidal rock of reddish gray color, consisting of turbid plagioclase crystals, of reddish brown, non-transparent augite and of disseminated clusters of magnetite; the interstitial pseudo-amygdules are filled with calcspar and with the green, serpentine-like mineral inclosing radiated, concretionary masses of delessite.

North of the Ahmeek mine, on the road to the Cliff mine, a number of abandoned mines are found at the base of the Greenstone Range, which from here to the end of Keweenaw Point forms a conspicuous chain of high mountains with brisk escarpments on the south side.

All the before described mines were opened in beds parallel to the stratification; from here northward we find, with few exceptions, only transverse fissure veins mined. The discovery of such transverse seams, filled with a rock material obviously different from the surrounding wall-rock could readily be made in the mural rock escarpements, and the large amount of copper found in many of them directed the attention of the miner in this part of the country principally to them, although many of the amygdaloid belts were cupriferous, some sufficiently rich to be successfully mined.

As a rule, these fissure veins were found to contain little copper, while intersecting the compact masses of the diabase, called "greenstone" by the miner, but became particularly rich in the metal during their intersection of the softer porous amygdaloidal belts. Frequently, from the transverse vein the miner drifted sideways into such amygdaloidal beds, finding them rich enough to remunerate for the work.

Much of the copper in the veins is found in large masses, some many tons in weight; quite often also silver is found in association with the copper. The Cliff mine is the oldest and most widely known mine in this part of Keweenaw point, once very successful, but since a good while very little worked, and at present left idle. The fissure vein which it followed was naturally exposed in the bluffs and is yet observable from the valley below, as the portion in the higher part of the bluffs was not touched by the miner. In this outcrop we see not a single larger fissure filled with vein matter, but a great many sub-parallel smaller fissures, in reticulated connection with larger segments of wall-rock between, or in the wider parts of the vein the cleft was evidently first loosely replenished with debris of the wall-rock tumbled into it, which subsequently became cemented into a breccia by infiltration of the different mineral solutions which deposited the so called vein matter. The minerals constituting it principally are quartz, prehnite, calcspar and laumonite; more subordinate is the occurrence of analcite, apophyllite and various other zeolitic minerals, besides orthoclase, datolite, etc. The copper in various modes associated with these minerals is evidently, like them, deposited from a solution of copper, most likely by galvanism. It penetrates the other minerals in finer reticulated films or in delicate leaflets, or it has adapted itself in coarser masses to the interstices left between the other minerals; more rarely it formed in druse cavities and could then develop itself in its own crystalline form in manifold modifications, which are highly esteemed by naturalists and more so by the tribe of curiosity hunters which sometimes offer fabulous prices for them. The large masses of copper are generally found embedded in calcspar associated with laumonite, prehnite and epidote. As the vein of the Cliff mine was found not to contain much copper within the massive rock belts which form the higher part of the bluffs, it was followed into the underlying deeper strata which dip under an angle of 30 degrees to the northwest. The strike of the vein is almost at right angles to the trend of the formation and its position is little deviating from the vertical.

From the maps of the mine we learn that about thirty different strata of alternating compact and amygdaloidal diabase belts have been sunk through in following the fissure vein downwards from the base of the Greenstone bluffs, where a narrow sedimentary seam, the so called "slide," represents the Allouez conglomerate belt. The deepest levels are about 1,600 feet below the top of the Greenstone bluffs; the farthest shaft, No. 2, is about 1,750 feet south of the bluffs, its depth is 400 feet, and, according to the calculation of the dip of the strata, the northern shaft, 1,600 feet deep, is about on the same stratum as shaft No. 2, 400 feet in depth.

Various of the amygdaloidal belts met with in mining the fissure vein were found so rich in copper, that drifts were sideways driven into them at different levels, and the last work done in the mine by tributors was in these side-drifts. Three years ago, Mr. Brockaway, the agent of the mine, made extensive explorations south of the old shaft of the Cliff mine, using the diamond drill and giving it a direction so as to intersect the strata vertically to their bedding. The drill holes are not all located in a straight line, but their relative distances southward were determined by measurement.

The first drill hole is 750 feet south of shaft No. 2; its depth is 148 feet. The rock beds intersected were as follows: First, an amygdaloid belt carrying some copper, then a blackish colored compact diabase. At the bottom of the hole a thin seam of a reddish colored jaspery rock was struck, which is 1,290 feet vertically beneath the base of the Greenstone bluffs. The miners consider this jasper belt as the equivalent of the Calumet conglomerate.

A second drill hole, 365 feet deep, is 750 feet south of the former; it intersects five belts of alternating amygdaloidal and compact diabase layers.

Three hundred and twenty-five feet south of the latter drill hole, a shaft has been sunk to the depth of 65 feet, which is supposed to intersect the second diabase belt and the third amygdaloid belt of the former drill hole. The amygdaloid is rich in small masses of copper, its vertical distance from the jaspery seam, believed to be the Calumet conglomerate, is 532 feet, and the identity of this belt with the Osceola amygdaloid is suggested.

A second shaft, 125 feet deep, is sunk 500 feet south of the other, 700 feet east of the northwest section corner of Sec. 6, T. 57, R. 31, which is supposed to penetrate the fourth diabase belt and the fifth amygdaloid belt of the last diamond drill hole. At the same time it is sunk on a fissure vein, six feet wide, which carries a fair amount of copper in small masses, associated with calcspar, prehnite and quartz.

One thousand feet south of this deeper shaft, another drill hole commenced in a massive diabase belt, then succeeded an amygdaloid, and so four times in alternation to a depth of 260 feet, where a conglomerate, about two feet wide, occurred, which is thought to represent the Kearsarge conglomerate. The vertical distance of this conglomerate from the above mentioned supposed Osceola amygdaloid, is 810 feet.

Two hundred feet farther south a drill hole, 361 feet deep, penetrated below the conglomerate, first, an amygdaloidal belt, then compact diabase.

Three hundred and twenty-five feet south of this, another drill hole, 328 feet deep, commenced in the diabase belt next above the conglomerate and intersects, besides the amygdaloid and diabase belt penetrated by the former drill hole, another amygdaloid and underlying diabase belt.

Six hundred feet south, another drill hole, 266 feet deep, went through various modifications of diabase.

Three hundred feet south of this, by boring to a depth of 296 feet, several alternations of compact and amygdaloidal diabase were struck beneath a thick cover of drift deposits.

The last of the drill holes, 300 feet south of the former, went all through drift, barely touching the solid rock at the bottom.

The total of the explored ground south of the bluffs of the Cliff mine comprises 2,632 feet of strata, measured vertically across their bedding. A continuation of this cross-section northward, from the base of the Cliff mine bluffs to the lake shore at Eagle River, a distance of over two miles, is given by the accurately measured cross-section from the Phœnix mine to Eagle River, prepared by Mr. Marvine and published in Prof. Pumpelly's report, to which the reader is referred. We learn from it the thickness of the rock complex composing the Greenstone Range proper, to amount to about 1,500 feet of strata. The lower beds are dark blackish colored, rather fine-grained; most of them have the peculiar structure described by Prof. Pumpelly as "lustre-mottled," which structure, however, is observed in a great many other Keweenawan diabase belts in higher and in lower horizons. The strata forming the top of the bluffs and a number of other succeeding diabase belts arc coarsely crystalline, some darker, others lighter colored, but in composition the entire complex of beds composing the Greenstone Range differs very little; they all consist of transparent plagioclase and augite crystals (which latter have in their sections a pale yellowish brown color) in intermixture with a variable proportion of olivine and magnetite grains, which both are frequently clustered together. The plagioclase is in some of the rock belts partially turbid, the augite has rarely suffered much alteration, but the olivine is almost regularly peripherically altered into a green, minutely crystalline substance, or else a purplish, brown colored area surrounds the olivine grains. Not uncommon in the coarsely crystalline variety of the rock are pseudo-amygdules replenished with the soft green, serpentine-like mineral which enters into the composition of almost every diabase of the Keweenaw group. In the upper horizon of the just described complex of rocks, next to a fissure vein once worked by the *old* Phœnix mine, a very coarsely crystalline red and black speckled diabase belt occurs, in which red orthoclase seems to have taken the place of the plagioclase, but on examination of thin sections these turbid crystals frequently show yet a dimly marked polysynthetic striation, and most likely all of them are plagioclase crystals altered by a cloudy infiltration of ferruginous pigment. The augite is partially altered into chlorite, but some of the crystals are perfectly fresh and translucid. This rock encloses also a large number of colorless apatite prisms. A very similar rock occurs at the Mendota mine near Lac La Belle, which evidently occupies an entirely different horizon in the series. North of this group of coarse-grained diabases, the so called greenstones follow, a wide belt almost exclusively formed of diabasic rocks, which amounts in the aggregate to a thickness of 2,000 feet. Most of these are quite fine-grained, rather dark colored, and often porphyritic by segregation of larger feldspar crystals within the fine-grained ground mass; the compact belts alternate with amygdaloidal seams, of which one is particularly to be mentioned as being cupriferous, the so called Ashbed of the miners. This belt is quite large, locally from 50 to 150 feet wide; in many places along the west shore north and south of Eagle River we find mines opened on it, but with the exception, of the Copper Falls mine, all others are presently abandoned; the *old* Phœnix mine in former times worked in it extensively.

North of the Ashbed, which is overlain by a thick belt of compact, fine-grained diabase, speckled by segregated larger plagioclase crystals disseminated through the dark gray ground-mass, succeeds another complex of rocks, amounting to about 1,200 feet of strata.

In the previously described series, amounting to a thickness of over 3,500 feet, sedimentary layers were excluded, with exception of some seams connected with the Ashbed, while in the group presently under consideration, numerous sedimentary rock seams are found to alternate with the diabasic rock belts. In Mr. Marvine's section we see not less than ten sandrock and conglomerate belts interstratified within the space north of the Ashbed and south of the large conglomerate, almost a mile in thickness, which forms the shore part of the land near Eagle River village. The diabasic rock belts intervening have nearly all an amygdaloidal structure; most of them are middling fine-grained, but also coarser crystalline seams occur, as for instance, the uppermost bed underlying the great conglomerate at the cascade near Eagle River village. Various of these amygdaloidal rock seams are copper-bearing, but so far the miner has paid little attention to them.

The lowest beds of the great conglomerate belt which terminates the Eagle River cross-section, are fine-grained sandrock beds inclosing distantly scattered pebbles; 60 or 70 feet above the base coarse conglomeratic strata succeed which in the ascending cross-section presented in the river-bed are frequently interposed again with seams of red colored sandrock. The pebbles composing the conglomerate are in the majority formed of different varieties of red colored porphyry; a part is homogeneous, fine-grained, without imbedded larger crystals; others inclose in this groundmass large crystals of feldspar, alone or associated with large grains of glassy quartz; still others have a completely crystalline, granite-like structure.

A small proportion of the pebbles consists of compact and of amygdaloidal diabases; the cavities of the amygdaloid pebbles are replenished with the usual variety of minerals, and it is distinctly observable that these minerals were already filling the cavities of the rock before its waterworn fragments became part of the conglomerate bed.

At Eagle River the width of this conglomerate belt is not visible, as it continues far out into the lake, but at Eagle Harbor it is found to be about a mile wide and on the north side succeeded again by diabasic rocks which project in a row of cliffs along the shore line and form the foundation of the lighthouse at the entrance to the harbor.

The above mentioned Ashbed, in the vicinity of Eagle River, a belt from 80 to 100 feet in width, consists of dark brown, earthy-looking rock masses, readily decomposing into small fragments on exposure, which are a brecciated mixture of fragmental amygdaloid masses partially worn and rounded, with a dark brown, fine-grained, interstitial cement-mass of dull fracture, which is evidently of sedimentary nature. Sometimes this sedimentary material prevails and the amygdaloidal rock is distantly imbedded in it; other times the amygdaloid forms the greater bulk, and narrow seams of the sedimentary rock mass unite them. At the North Cliff mine well laminated, dark brown, compact sandrock ledges are found interposed between the amygdaloidal portions of the belt.

The amygdaloidal rock varies in quality; most of it has the fine-grained structure of the so called Ashbed diabase and groups of porphyritically segregated feldspar crystals are scattered through it; the color is usually reddish brown, sometimes grayish; part of it is compact, hard, other portions are soft, porous. The amygdules consist of calcspar, laumonite, delessite and quartz; in some parts of the old Phœnix mine nearly all amygdules are filled with transparent, glassy datolite, which is rose-colored by intermingled fine scales of copper; some of the amygdules are almost entirely filled with copper, but the main mass of the metal occurs in hackly masses in interstitial fissure s earns.

In the North Cliff mine, old Phœnix mine, Garden City mine and Copper Falls mine, all of which are opened in the Ashbed, transverse fissure veins intersect this belt, which contribute a large share to the product of the mines.

Some of these veins resemble in rock character the fissure vein of the Cliff mine, being of quartzose and prehnitic nature; others are prevalently composed of calcspar, laumonite and datolite, which minerals form the cement of angular fragments of the wall rock which fell into the crevices, and constitute with them a breccia.

The amygdaloidal rock adjoining these brecciated veins is at the Copper Falls mine and the Garden City mine often much altered into a dark green rock mass, full of irregular cavities and crevices which are replenished with intensely red colored analcite crystals associated with prisms of natrolite and with calcspar. The green mother-rock consists to great extent of an amorphous, serpentine-like mass, mingled with radiated delessite concretions, which rock mass is by gradations linked together with the less altered amygdaloidal rock, and betrays its being an alteration product of the latter.

At the Copper Falls mine a tunnel 4,525 feet in length has been driven into the hillside horizontally across the strata dipping under an angle of 27 degrees to the north. Two thousand eight hundred feet of this length from the entrance of the tunnel are made up by an alternation of amygdaloidal and compact diabasic belts with five different belts of sandrock or respectively conglomerates; then comes the Ashbed which in its intersection is 150 feet wide; beyond this the tunnel is continued for the distance of 1,560 feet, intersecting an alternation of amygdaloidal and compact diabase belts. I omitted to give the measurements of all the intersected beds recorded in the journals of the mine as not of sufficient interest for the generality of the readers.

North of the adit of this tunnel the great conglomerate belt mentioned before in the Eagle River section, is near by exposed, and fills the entire interval from here to the lake shore, a mile in width. Outside, in the lake, a row of cliffs of diabasic rock projects, which are the same belt which at Eagle Harbor forms part of the mainland at the lighthouse point. This outer amygdaloidal diabase belt is intersected by copper-bearing veins from which, by superficial trenching, large masses of copper had been extracted by miners many years ago; the opening's are at present all filled with water.

The (new) Phœnix mine, located in front of the Greenstone bluffs, next to the gap through which Eagle River finds its outlet toward the lake, works in a similar fissure vein as the Cliff mine. The geological structure of the succession of beds intersected by the mine is about the same as in the Cliff mine; also here the Allouez conglomerate is merely indicated by the so called slide, while intermediate between the two mines, not much over a mile apart, a narrow conglomerate seam is found in this position, naturally exposed at the base of the vertical cliffs.

At the hundred-fathom level of the Phœnix mine another sedimentary seam occurs, which, in lower levels, widens to six and even ten feet, and then shows the nature of a conglomerate. This belt, supposed to be the equivalent of the Houghton conglomerate, has not been met with in the Cliff mine, but it is represented in the Central mine, four miles northeast of the Phœnix, which mine likewise follows a fissure vein and has its shafts at the base of the greenstone bluffs.

Between the two mines is another working mine, the St. Clair mine; it follows a fissure vein of the same lithological character as the other mentioned fissure veins.

At the Central mine, the Allouez conglomerate is well developed, in a thickness of 15 to 20 feet; it contains no appreciable quantity of copper there. The other conglomerate, believed to be the equivalent of the Houghton conglomerate, is struck in Shaft No. 2, at a distance of 665 feet below the Allouez conglomerate exposed at the base of the bluffs. The thickness of this belt is about eight feet; its cement, and partially also its pebbles, have been much altered and transformed into a porous, light yellowish green epidote mass, which is richly impregnated with copper, but the miners simply passed through it without drifting sideways into the ledge. Lower down, in the 160-fathom level of the same shaft, another conglomerate seam is struck, which is only three or four feet in thickness, but remarkably rich in copper. Here side-drifts are opened into it, which contribute a good share to the product of the mine. The vertical distance of this belt from the Allouez conglomerate is 1,100 feet; it is thought to be the analogon of the Calumet conglomerate.

The fissure rock of the Central mine has the same nature as that of the Cliff and Phœnix mines; it was very rich in its upper levels, but going down on it a general decrease in its productiveness was observed, and it was feared for a while it might grow poorer in the same rate by sinking deeper on it, but later work opening deeper levels disclosed again a wealth of the vein equal to that of the richest portions of it in the higher levels.

Much of the copper in the Central mine occurs in larger masses, some a good many tons in weight, which are surrounded by calcspar, prehnite, laumonite, and quartz, and have usually not their own crystalline form, but are adapted to the interstices left between the other minerals; sometimes, however, the copper formed in free cavities and then is found in most beautiful crystals associated with similarly perfect crystals of calcspar, apophyllite, analcite, natrolite, datolite, and quartz; likewise is silver a frequent associate of the copper.

These mineral specimens rarely come into the hands of the mining officials, and are an article of trade to which the laborers of the mine think themselves privileged. The number of travelers visiting the copper region, all desirous to gather some of these curiosities, have in the course of time caused the venders to raise their prices to fabulous height. Specimens of crystallized copper bring from five to twenty-five dollars and more, and an instance is known to me where a crystal of calcspar of the size of a hen's egg was, from the first hand, sold for eighty dollars, and the second purchaser paid ninety-five dollars for it. East of the Central mine, along the base of the Greenstone range, a great number of old mining locations are met with which have been for a good while abandoned. All followed transverse fissure veins, and from some of them a considerable amount of copper was gained.

The next place where work is done is the Delaware mine, which formerly mined a fissure vein, but now, in the hands of new owners, is called the Conglomerate mine, as the Allouez conglomerate belt is the stratum which is mined for copper. Outcrops of this rock belt are noticeable all along the base of the bluffs from the Central mine to the Delaware mine. In some of these localities the belt is not over three or four feet wide; in others it has a thickness from 20 to 30 feet, which is the case at the Delaware mine. The dip of the strata at the mine is 23 degrees to the north. The copper is very unequally distributed in this rock; large stretches of the belt are almost barren of the metal, then again patches are met with which are very rich; a good portion of the mined rock has therefore to be rejected. The average yield of the rock sent to the stamps is not over one and one-fifth per cent, but it is expected to make even this low percentage profitable by operating on a large scale. For this purpose the company erected a new stamp mill at Lac La Belle, and connected it with the mine by a railroad seven miles long. The mill has three large Ball stamps, of which two are in constant use; they are capable of stamping two hundred tons of rock daily.

The succession of rock beds underlying the conglomerate belt of the mine is to the extent of 400 or 500 feet of strata naturally exposed on the lower part of the hillslope. It is an alternation of amygdaloid belts, some of which are cupriferous, with compact diabasic belts. Farther south, most of the surface is covered with drift deposits, and the few rock projections seen at intervals are too far apart to learn by them much of the details in the succession, but we observe a conformity in strike and dip of the beds from the Delaware mine down to Lac La Belle, can therefore, with propriety, suggest that in going to the lake we meet constantly with lower strata.

By explorations with the diamond drill the occurrence of the two conglomerate belts intersected by the shafts of the Central mine has also at the Delaware mine been ascertained. The first, thought to be the Houghton conglomerate, is found not far from the old stamp mills in the sole of the valley. The second, identified with the Calumet conglomerate, has been struck 400 feet beneath the surface, southeast of the location, not far from the bridge across Montreal River. A third belt of conglomerate, 150 feet wide, is intersected by a railroad-cut two miles south of the former place, near the center of Sec. 30, T. 58, R. 29. A large proportion of the pebbles of this belt is amygdaloidal and compact diabase; the balance is made up by porphyry pebbles; the cementing interstitial seams are much impregnated with epidote, but no copper seems to occur in it. Not many steps off from this place conglomerate boulders are mingled with the drift masses, which are richly impregnated with copper in the form of malachite. They seem not to belong to this belt and are probably transported from a northern belt.

South of this conglomerate belt unto the shore of Lac La Belle a great number of diabasic and amygdaloidal rock belts are found exposed along the railroad track and the wagon road, but several intersecting rock seams which I will describe below are not seen in these routes denuded.

Next to the conglomerate succeeds a fine-grained compact diabase of black color, which cleaves in even slabs an inch or two in thickness; the same rock is largely exposed on top of Bohemian Mountain at the Mendota location.

Farther south several amygdaloidal belts of purplish brown color with epidote, calcspar, and delessite amygdules occur; one of them is on the cleavage faces coated with malachite. These alternate with belts of compact diabase which contain numerous epidotic seams recementing the shattered rock masses.

The lowest rock belt in this large succession is a conglomerate 80 or 90 feet thick which projects in high bluffs short distance off from the lake shore. The stamp mills are built close to their front, whereby the advantage is gained of dumping the rock from the railroad cars into the building, a story above the Ball stamps.

This conglomerate is much darker colored than the conglomerates north of it; the cement consists of trappean debris and is locally impregnated with epidote; the pebbles are also in a great measure formed of diabase and amygdaloidal rock. The porphyry pebbles are nearly all of the fine-grained, homogeneous jaspery kind, which rock occurs in a large belt interstratified with the diabasic rocks of the Bohemian Range at Mount

Houghton, and from there extending six or eight miles farther to the east without interruption. Not only rounded pebbles of this porphyry enter into the composition of this conglomerate, but a great quantity of such rock is enclosed in sharp, angular fragments, sometimes even in large blocks. The rock belt is much decayed on the surface. An efflorescence of malachite on the rock faces is frequently noticeable, but it does not contain any larger quantity of copper.

Ascending from the lake shore to the Mendota mine on top of Bohemian Mountain, we see first, near the dwelling houses at the base of the mountain, the before mentioned conglomerate exposed in the road bed. Above it an alternation of amygdaloidal seams with epidotic diabase belts succeeds, amounting to about 120 or 130 feet. Next higher follows a large belt of fine-grained, dark blackish, gray colored, glistening diabase, exhibiting the so called lustre-mottled structure. The plagioclase in its composition is turbid, rarely exhibiting poly synthetic striation; the augite is in part unaltered, transparent with pale brownish color; another part is green colored and of fibrous structure, indicating its transformation into hornblende; in addition to these, numerous olivine grains are disseminated, besides magnetite, which two latter minerals are always found closely associated.

In the farther ascent we find about midways of the mountain slope a very wide belt of coarsely crystalline rock, described by earlier writers under the name of syenite, and recently by Prof. Irving as orthoclase gabbro. It consists of about equal quantities of red feldspar, probably all orthoclase, and of uralitic hornblende crystals, which under the microscope very frequently enclose remnants of unaltered augite, of which they are a paramorphic product. Clusters of magnetite crystals or might-be titan-iron are copiously disseminated, besides translucid grains of quartz and epidote crystals; in some but not in all of the sections apatite prisms occur. The red color of the feldspar is not uniform, and is due to a seamy or cloudy infiltration of hematite pigment into the originally colorless mass. The rock above described as wall rock of a fissure vein at the old Phœnix mine is very similar to this rock. The red feldspar crystals in this latter are not all orthoclase, as some exhibit polysynthetic striation; a part of the augite in that rock is perfectly fresh and transparent and the altered crystals of it have not the perfect cleavage of the hornblende as in the rock of Lac La Belle; oftener the transformation appears to have resulted in the production of chlorite. Intimately associated with this rock belt are seams of a red colored crystalline rock which resembles the granitoid pebbles in the Calumet and other conglomerate belts. It consists of an aggregation of red orthoclase crystals with distantly interspersed altered crystals of augite changed into a whitish, soft, steatite-like mineral intermingled with chlorite scales. Between the interstices of the orthoclase crystals occurs a good proportion of transparent quarts grains of very irregular shape; also magnetite granules are sparingly scattered.

This rock is merely a modification of the orthoclase gabbro, in which by local segregation the feldspathic constituent large y prevails over the augitic. Its seams are rarely sharp defined from the adjoining gabbro; they merge with each other by gradiations.

This red rock must not be confounded with the red porphyry forming the summit of the neighboring Mount Houghton; there is no analogy between them.

A very good opportunity to see exposures of the gabbro and the associated red rock is offered by the lower adit of the Mendota mine and in the ravine above it. On the burrows in front of the adit a large amount of a dark green, coarsely crystalline rock is thrown out, which microscopically shows the distinct outlines of the former feldspar crystals and intermediate augite crystals originally composing it, but the entire mass is changed into a soft, steatite-like substance, which in thin sections under the microscope shows a minutely crystalline aggregate polarization; the former augite crystals appear more turbid and darker than the pseudomorph of the feldspar crystals, and the interstices between these are filled with quartz. Magnetite is disseminated in clusters as in the orthoclase gabbro, of which I suppose this rock is a pseudomorphous product.

In the same horizon occurs a belt of coarsely crystalline olivine gabbro, which in hand specimens is not distinguishable from the same rock found in the Penokee region or at Duluth. Its components are transparent crystals of plagioclase, pale brownish augite, and yellowish green olivine, besides some magnetite or titan-iron. Large, freshly quarried blocks of this rock were piled up on the roadside, together with blocks of the orthoclase gabbro, to be used as building material for the Lac La Belle stamp mills. I did not succeed to find this rock belt in the quarry, some distance above, on the hillside, but the rock unquestionably came from there. Above the orthoclase gabbro belt, which is not much less than 200 feet thick, succeeds an almost equally large belt of a gray, lustre-mottled diabase, projecting in vertical cliffs on the summit part of the hillslope. It is middling fine-grained; the augite is almost completely changed into hornblende. Considerable similarity exists between this rock and the other diabase next below the orthoclase gabbro. Farther back on the plateau of the hill, a very fine-grained, compact, black colored diabase belt succeeds, which is the same as the before mentioned rock found exposed on the roadside at the base of the north slope of the hill. Next above it is an amygdaloid belt, and this is overlain by a conglomerate belt which is probably the same as the one intersected by the railroad track first met with, coming from the Delaware mine.

The just described succession of rock beds composing Bohemian Mountain, is transversely intersected by numerous fissure veins, filled with calcspar in association with chalcocite.

A number of years ago extensive preparations were made to mine these veins, but after a few years trial the work was abandoned, as the amount of copper ore obtained would not repay for the expense of mining it.

The lower division of the Keweenaw group composes the range of hills east of Bohemian Mountain, between the shore of Bête Grise Bay and the valley of Montreal River. The shore line is, with the exception of a few sand beaches, bordered with rock cliffs all the way out to the end point of the Peninsula, and offers, therefore, an excellent opportunity to examine this part of the group.

In several localities along the shore the discordant contact of the eastern sandstones with the Keweenaw rock series is observable.

One of such localities is situated near the quarter-post on the south line of Sec. 26, T. 58, R. 29, about a half a mile northeast of the outlet of Lac La Belle into Bête Grise bay. We see there a large succession of light colored, whitish and red blotched sandstones, alternating with several narrow seams of a dark colored, reddish brown breccia, consisting of small, little water-worn, fragments of diabasic and felsitic rocks like those largely exposed in the cliffs adjoining the shore. This group of sandrock and breccia beds dipping under an angle of about 35 degrees southward, is seen in immediate contact with a belt of lustre-mottled diabase which dips under a high angle to the north. The diabase belt is very much shattered and recemented by a network of calcspar and laumonite seams; it alternates with intermediate conglomeratic seams formed of rounded and of angular fragments of compact and of amygdaloidal diabase, and of an abundant cement of a dark reddish brown colored, fine-grained, sedimentary material, which generally has a dull earthy fracture, but often also is quite compact and has a smooth, conchoidal, almost flinty fracture. It resembles in this latter case most strikingly the red felsites of which I will have subsequently to describe large exposures.

The line of contact between the sandrock and the diabasic rocks is seen in part above the water-level, but much of it submerged in shallow water, and is plainly visible for the distance of about a quarter of a mile eastward; the succession of sandrock ledges is observable far out into the lake; many of them exhibit ripple-marked surfaces. About a mile northeast of this locality is the summit of Mount Houghton, 847 feet high; its slope towards the lake is formed by various modifications of fine-grained diabase with interposed amygdaloidal seams; the top part consists of a red, fine-grained felsite belt, amounting to great thickness; the north slope of the mountain is formed again of a succession of diabasic rock belts. This felsitic rock exhibits very frequently a distinctly banded, laminated structure; it is hard, very brittle, and breaks under the stroke of the hammer into numerous sharp-edged, irregular fragments, so that only with difficulty hand specimens of a desired shape can be procured. A close relationship exists between this rock and the quartz porphyries which form the majority of the pebbles in the Calumet conglomerate, as far as the ground mass is concerned, but it rarely incloses porphyritically segregated, larger single feldspar crystals or quartz grains.

Thin sections of the felsite of Mount Houghton appear under the miscroscope as an aggregate of turbid feldspar crystals, with dimly defined prismatic outlines, in intermixture with very irregularly shaped, indented or ramose masses of transparent quartz, both minerals constituting a network of which one fills the meshes of the other. Very often we find also the longitudinal axis of the two minerals directed in conformity with the lamination in the banded portions of the rock. As an additional component have to be mentioned copiously disseminated black molecules which, in part at least, are magnetite or martite granules. Some of the darker grains show a degree of transparency with brownish green color, which might be augite.

In polarized light, under crossed nicols, we observe a network of dark seams inclosing luminous dots recognizable as feldspar or patches of quartz; on revolution of the object the dark portions become, in some position, luminous, once this part and another time another; actually isotropic portions of the mass I could not observe or discover. Identical felsites with the Mount Houghton rock, composed the next high hill, one mile and a half east of the latter and a half mile south, very close to the shore; it occupies the north half of Sec. 29, T. 58, R. 28, presenting high vertical cliffs. The lower outlines of the belt, close to the water's edge, which most likely are loosened masses, slid down, repose oil the lustre-mottled diabase rock, which, with local interruptions by the before mentioned brecciated or conglomeratic amygdaloidal rock seams formed the shore-cliffs from the place where the eastern sandstone is seen in contiguity with them, up to here. The felsite of these shore-cliffs has the structure of a breccia; its cementing seams are often infiltrated with malachite or with red oxide of copper.

Not quite a half mile east of the shore-cliffs of felsite, near the center of Sec. 29, another large patch of the eastern sandstone is seen in contact with the lustre-mottled diabase. The inclination of the sandrock beds in this place is not quite as steep as it was in the first described locality; still they have a distinct southern dip, steepest off shore, and diminishing toward the shore, near their contact line with the diabase, where the strata have an almost completely horizontal position, which circumstance makes me suggest as the possible cause of the inclined position of the strata an underwashing of the beds in the lake-bottom and the subsequent breaking down of the more superficial strata. Their discordance with the diabasic rock belt is here just as plainly observable as in the former place; crevices in the diabase are often found replenished with sandrock.

Leaving this place, we find eastward to the mouth of Montreal River, constant exposures of conglomeratic and brecciated rock masses formed of diabasic and amygdaloidal fragments, cemented by an abundant sedimentary interstitial mass, which entered the superficial cavities of the amygdaloidal rock, in proof that they were not already replenished with other minerals at the time the fragments became embedded in the conglomerate.

At times the conglomerate rock recedes from the shore and the underlying lustre-mottled diabase forms the borders of the lake; its presence is recognizable from a distance by the conspicuity of the network of spar and laumonite seams intersecting it in all the exposures on the whole length of the shore.

The cementing seams of the amygdaloid conglomerates consist usually of a fine-grained, dark purplish brown colored, not very hard mass, with a dull earthy fracture, but locally it is found to be very hard and compact, with a smooth, almost flinty fracture, in which condition its resemblance to the before mentioned felsitic rock masses is so great as to make it difficult to distinguish one from the other.

Montreal River runs over a stairlike succession of cliffs into the lake, which cliffs consist of the often before mentioned lustre-mottled diabase, whose thickness here is seen to be quite large; the strata dip under a high angle northward, like all the remainder of succeeding rock beds. North of this belt follows a repeated alternation of amygdaloidal seams, with others of compact diabase. At the first great bend of the river a little more than a quarter of a mile from the shore is an amygdaloidal conglomerate belt exposed in the bed of the stream; interstratified and alternating with these layers are several seams of compact diabase from six to eight feet wide. Farther north, compact diabase rocks are incumbent, which amount to greater thickness. Next above follows a wide belt of a very fine-grained, dark purplish brown colored, hard but very brittle rock, which, under the microscope, shows the structure of the so called Ashbed diabase; its irregular splintery cleavage makes it somewhat resemble very dark colored specimens of a felsitic rock. It forms the foot-wall of a large belt of felsite in brecciated condition, and above this breccia follows a still larger belt of a coarse conglomerate, formed of rounded and angular felsite pebbles, besides a good proportion of amygdaloidal and diabasic pebbles.

The brecciated rock consists of small, angular fragments of brick-red felsite, firmly cemented together by interstitial seams of somewhat different shade of color, but of almost the same quality as the enclosed pebbles. Within these seams are numerous well formed feldspar crystals seggregated, and with them small morsels of diabase are found plentifully disseminated. The position of this breccia belt is in the line of strike with large felsite outcrops on the east and west sides; its relation to the incumbent conglomerate, which essentially is composed of the same rock material, I was not able to ascertain, as the interval between the exposures of the two belts is covered with drift masses.

North of the conglomerate belt the trail along the river up to the Girard mine leads across several disconnected outcrops of diabasic and amygdaloidal rock belts, but for long stretches the surface is covered with drift masses; therefore not much could be learned of the succession of strata in this part. Proceeding along the shore east of the mouth of Montreal River, the shore is found lined with high bluffs of the lustre-mottled diabase, intersected with reticulated seams of calcspar and laumonite, which rock masses locally change into a conglomerate mass, composed of diabase and amygdaloid fragments, rounded and angular; often also a good proportion of epidotic rock masses are mingled in. The cementing mass as before described is a dark brown, fine-grained, sedimentary mud mass, which in cloudy blotches has the nature of a pale green epidote rock, clearly being the result of a secondary paramorphosis.

In the small bay used as a fishing station, on the south line of Sec. 26, T. 58, R. 28, a large isolated outcrop of felsitic rock masses projects in high cliffs at the shore; a quarter of a mile east of it we find the promontory forming the opposite side of the bay, totally composed of felsites which here protrude in a belt at least 500 feet in thickness. The rock mass is the same as that of the summit of Mount Houghton and of the large hill in the north half of Sec. 29. Locally the rock has a brecciated structure, but the great bulk of the belt is a homogeneous solid mass, full of cleavage cracks; its color is brick-red or purplish brown; a laminated, seamy structure of the rock bed is sometimes observable, but not in a degree as the rock of Mount Houghton and other more eastern outcrops exhibit it. On the north side of this belt a belt of porphyritic diabase is seen to overlie it, which consists of a minutely crystalline diabasic groundmass, enclosing numerous delessite amygdules, besides a large amount of red feldspar crystals, many of the size a half an inch in length. This is the only locality on Keweenaw Peninsula where this kind of a diabase occurred to me, while in the Gogebic Range this variety of diabase is very common. Of the same rock disseminated with very large feldspar crystals, in clusters, consists also the greatest part of the diabase pebbles inclosed within the large conglomerate belt on Siskowit Bay at Isle Royale. The promontorial point on the line between Secs. 35 and 36 consists of the same porphyritic diabase which forms the hanging of the felsite belts from here further east, to the old location of the New England mine in Sec. 30, T. 58, R. 27; we find four different belts of felsitic rock, interstratified with diabase belts and amygdaloidal conglomerate seams. The first felsitic belt is found near the center of the south line of the S. W. ¼ of Sec. 25; it has a brecciated structure and differs from the ordinary felsite by a peculiar state of decomposition, being porous, gritty, resembling a sandrock; otherwise it perfectly corresponds with the brecciated felsite masses of which several other belts occur some distance further east. The thickness of this belt is only about five feet, and it dips under a high angle north.

On the east side of this narrow belt of brecciated felsite follow compact beds of diabase in alternation with seams of the often before encountered amygdaloid conglomerate. Near the east line of T. 58, R. 28, occurs another belt of brecciated felsite, then again, compact diabase beds and amygdaloid conglomerate east of it.

In Sec. 30 of the adjoining town, R. 27, the shore is almost through the entire width, of the section bordered with outcrops of a very large felsite belt which trends parallel with it, dipping under an angle of about 70 degrees to the north.

The felsite has in this locality a remarkably well laminated, banded structure by regular alternation of differently colored, narrow, almost linear seams, which banded structure is particularly obvious on weathered surfaces. A succession of such regularly laminated beds, amounting to near a hundred feet, is exposed on a peninsular spur of cliffs projecting into the lake, and traceable far out beneath the water-level.

The incumbent higher beds of the felsite belt, cropping out on the beach, differ some from the very compact strata. Certain layers have a concretionary, spherulitic structure, which deceivingly resembles the concretionary structure not rarely seen in sedimentary rock beds. These concretionary beds exhibit like the others a laminated structure; the superimposed laminæ connect among themselves vertically by transverse bars likewise consisting of aggregated, warty globules of different size; some of them exhibit a fibrous radiation from the center. The intermediate space between these layers of very compact consistency are filled with a lighter colored, somewhat porous silico-feldspathic mass in progress of decomposition to kaolinite.

Another variety of the rock is composed of a reticulated intermixture of such concretionary nodules with a softer, dull, earthy-looking, red substance, which incloses large, whitish colored, much shattered feldspar crystals, the clefts of which are infiltrated with the red material.

Still another form of the rock is full of irregular, lobate, amygdaloidal cavities, lined with a coating of quartz crystals or of chalcedony, or completely filled with them. Often are leaflets of metallic copper inclosed by the quartz. Some other cavities are replenished with prehnite and other zeolitic minerals. Thin sections of this amygdaloidal felsite microscopically examined show the groundmass surrounding the amygdaloidal spaces to be formed of intimately reunited fragmental portions of felsite substance, some of which are homogeneous, compact, others seamy and cellulose. Amygdaloidal felsite masses occur also on the submerged reef of Stannard Rock lighthouse and in the Porcupine Mountains in the bed of the headwaters of Carp River.

The uppermost layers of this felsite belt are a coarse breccia of partly angular, partly rounded, water-worn felsite fragments with a light colored, porous cement, greenish colored by impregnation with malachite, which most likely is a secondary product of a small amount of metallic copper and of its red oxide, both of which are recognizable in the cement. This breccia is altogether different from the compact, brecciated felsite masses, previously described as occurring near the east line of T. 58, R. 28, and a mile north of the mouth of Montreal River. The cementing substance of these has the wavy, tortuous, fluidal structure, bending round the enclosed fragment, which is well represented on Plate 13, Figs. 9 to 12, in Mr. Irving's work on Lake Superior rocks.

The brecciated form of these rock belts first induced me to suppose their aqueous origin, as it is hard to imagine the injection of a fire-fluid mass into the accumulated mass of small fragments, some of which are diabase fragments, without causing a fusion of them, at least partially, but as the cement differs little from the material of the felsite fragments and incloses sharply defined feldspar crystals like they do, we must also admit that both formed in the same way.

The felsites of the Bohemian Range show in many other respects qualities as well compatible with a rock formed by aqueous interference as with an eruptive rock, but as the felsites are so closely allied with the quartz-porphyries composing the south belt in the Porcupine Mountains, and also represented in an exposure on the railroad above the Calumet stamps which bear indisputable marks of their eruptive origin, we cannot otherwise than presume the same origin for the felsites.

The occurrence of isotropic glassy portions observed by some microscopists in thin sections of felsite, which would be a positive proof of their eruptive nature, I did never observe with positiveness. A large proportion of the rock mass becomes dark under crossed nicols, but as far as in such minutely granular aggregate can be observed, every one of the dark molecules transmits light on revolution of the stage in a certain position; small, interstitial seams of glass substance might be overlooked, but as a rule these felsites are totally formed of individualized crystalline material.

The beds incumbent on the last described felsite belt are alternating, compact and amygdaloidal diabase belts, which present themselves in their succession by following the shore farther to the east, toward Union Bay. One of the diabase belts is crowded with globular concretions of radiated thomsonite masses, rose-colored by intermixture of delicate leaflets of metallic copper.

A great many fissure veins intersecting the diabase are observable on the shore; they consist principally of calcspar, laumonite and quartz; some of them are filled with prehnite charged with copper, which induced, years ago, some mining companies to establish locations on the shore, but, as the burrows show, mining was not continued long; the veins were found too poor in copper to encourage the continuation of the exploratory work. From Union Bay to the extreme end of Keweenaw Peninsula, I did not examine the shore outcrops. Seen from a distance, the northeast part of the bay appeared to be lined with arenaceous sedimentary rock beds.

Striking here from the shore northward, the densely timbered condition of the country offers no opportunity to see connected exposures of the rock beds until we approach the Greenstone Range, on which numerous abandoned mines are met with. We find the Keweenaw mine in the S. E. ¼ of Sec. 13, T. 58, R. 28, on the south slope of the Greenstone Range. Different amygdaloidal belts are uncovered here by the miner, and at the base of the cliffs the equivalent of the Allouez conglomerate crops out. The bluffs are formed of the coarsely crystalline diabase, which fully resembles the diabase composing the top of the bluffs at the Cliff mine.

On the north side of the range, the Vulcan, New York, and Michigan mines are situated.

Going west, we find the Philadelphia and Boston mines on the south slope of the range, and farther west the Star mine. Opposite the latter, on the north slope, is the Clark mine. On the south slope of the Greenstone Range a great number of different diabase and amygdaloid beds follow each other in alternate succession, all of which can be seen well exposed on the road leading from the Girard mine to the Star mine. At the crossing of Montreal River, a wide belt of diabase causes falls in the river about 30 feet high; overlying is a belt of amygdaloid, then succeeds a very dark colored diabase, and so on. Six or seven different amygdaloid belts, with intermediate diabase belts, present themselves before we reach the base of the Greenstone bluffs, at which the cupriferous Allouez conglomerate belt is seen in a thickness of about 35 feet; some mining has been done in it, but it was not a success. Several of the amygdaloid belts have been also mined at the Star location. One very hard, purplish gray amygdaloid, with prehnite and datolite amygdules, is quite rich in copper, but at present no work is done in it. Several transverse fissure veins, principally filled with calcspar and laumonite, had been followed on the Star location, but they were, with the exception of some local accumulations, poor in copper; likewise did I notice a prehnitic fissure vein opened on the location, which seemed to be more productive, but at present the places are altogether abandoned.

West of the Star mine are three or four other abandoned mining locations, on the south slope, which did some work in the Allouez conglomerate belt and in an underlying amygdaloid, besides mining fissure veins. Crossing the range at the Star mine, we find at the foot of the north slope the south shafts of the Clark mine, which followed a prehnitic fissure vein intersecting the very coarsely crystalline diabase characteristic for the upper strata of the Greenstone Range.

The feldspar in a great portion of the wall rock of the vein is red colored, the augite is bright, translucid, with yellowish brown color, and the large proportion of olivine in the rocks is almost completely changed into a dull green, serpentine-like mass and partially into radiated clusters of chlorite or delessite. Pseudo-amygdaloidal spaces in this rock are sometimes filled with prehnite which incloses scales of copper.

About 500 steps north of the shafts at the Clark mine, right by the dwelling houses of the location, a wide brecciated amygdaloid belt, with brown, gritty cement crops out; it resembles the Ashbed of Eagle River. It is traceable quite a distance east and westward and can also, at the Aetna mine dwellings, be seen well denuded, holding a similar distance north of the Greenstone.

North of this belt occurs, on the west side of the Clark mine, close to the road, a large belt of ripple-marked, brown sandstone, overlain on the north side by another amygdaloid belt. The sandstone has been quarried for building purposes at the mine.

Three-fourths of a mile north of the Clark mine dwellings, another fissure vein has been mined, known by the name of East vein. It intersects a large belt of fine-grained, black diabase, an overlying amygdaloid belt, and then the large conglomerate belt continued up to here from Eagle River.

An adit is driven horizontally across the diabase, within which the vein was not very rich; in the amygdaloid belt the vein became very productive in small masses, so called barrel-copper. The vein rock there, consisting of prehnite, calcspar, quartz, contains a great many druse cavities, lined with fine crystals of calcspar, prehnite, analcite, feldspar, epidote, quartz, and particularly datolite in brilliant, transparent form, often aventurine-like, glistening from intermixture with most delicate leaflets of metallic copper. The copper in the vein occurs frequently in solid, large crystals, but the angles between the crystal facets are obtusely rounded, never sharp. Entering the conglomerate belt, the vein loses its prehnitic character and becomes very poor in copper; it is there mainly composed of calcspar and laumonite. The drift into the conglomerate has only been driven for about 40 feet, and then abandoned. On the strip of land intervening between the dwellings and the adit of the east vein, considerable exploring work has been done in amygdaloid belts, of which several present themselves in alternation with compact diabasic rock masses, but although copper was found in all of these pits, the amount was too small to be profitably mined.

In this vicinity a belt of manganese ore occurs at the base of the before mentioned large conglomerate belt, and below an amygdaloid next succumbent beneath the conglomerate. The ore seam is from two to four feet wide, associated with calcspar; its foot-wall is a compact diabase; dip of the strata 50 degrees to the north. A small percentage of copper in the ore makes it unfit for some purposes, and the copious intermixture of calcspar is likewise depreciating its value; the mining of the ore has therefore been suspended since a good while. North of the large conglomerate belt, which extends to the shore of Copper Harbor, a belt of diabase full of agate nodules and delessite nodules projects in reefs in the harbor, and north of it, on the shore of the open lake, succeeds another conglomerate and sandrock belt, dipping northward in conformity with the other strata. A good many spar veins are seen to intersect these three last mentioned rock belts in the harbor, and in the bluffs at the shore. On the location of Fort Wilkins, in former years, a vein of black oxide of copper was mined, but at present all the pits are filled with drift sand, which covers the surface there to a depth of twenty and thirty feet.

On returning by the wagon road from Copper Harbor to the Delaware mine, my first starting point, I did not observe any particular geological features exhibited by natural outcrops or by the numerous abandoned mining places encountered on both sides of the Greenstone Range, which had not been seen before on the more eastern part of it, and not been already described. Nearly all of these mines were opened in transverse fissure veins.

The eastern continuation of the cupriferous conglomerate of the Delaware mine or the so called Allouez conglomerate shows itself in natural outcrops in many places on the side of the road, after it had crossed over to the south side of the range near the outlet of Mosquito Lake, which touches with its south end the north side of the Greenstone Range, and is bordered on the opposite, northern, end by a range of very conspicuous hills formed of the great conglomerate belt continued from Copper Harbor almost without any interruption to Eagle River and farther south, retaining a width of almost a mile. This same belt is found in great width yet at the stamp mills of the Allouez mine, but farther south towards Portage Lake it is not exposed on account of deep drift deposits covering this part of the peninsula, and from the position of another belt of sandrock beds supposed to be identical with the rocks of the Nonesuch mine of the Ontonagon district and therefore positively younger than the great conglomerate, we must suppose that in the vicinity of Houghton this belt, immensely large, has shrunk to a thickness of scarcely a few hundred feet, if it is represented at all.

(5) ONTONAGON DISTRICT.

The general character of the Keweenaw rock series is found in the Ontonagon district, and in the region of Gogebic Lake, to be about the same as on Keweenaw Peninsula, but it would be an unsatisfactory labor to make an attempt of an indentification of the subordinate strata of the series with those of the Portage Lake country, as in remote localities a correspondence of the single beds in a succession never can be expected.

Examining the succession of rock beds from the shore of Ontonagon, backwards to the Minnesota mine, a distance of about twelve miles, we find on the shore, three miles east of Ontonagon village, cliffs of red colored or white and red mottled sandstones which are nearly horizontal; they correspond in quality with the sandrock beds exposed farther east, near the entrance into Portage Lake Canal and on a great portion of the intermediate part of the shore. Entirely similar sandrocks with a dip not exceeding 10 or 15 degrees northward are found exposed west of Ontonagon in the different creek beds this side of Iron River; their dip is not due north, but somewhat inclined eastward. Back from the shore the surface is covered with deep drift deposits of a stiff red clay and only rarely a deep ravine gives a chance to see a few ledges of sandrock on its bottom. The deepest cut made by the Ontonagon River has only in a few places denuded these beds, so that we have very imperfect knowledge of the succession of strata for an interval of eight miles south of Ontonagon.

About two miles north of Rockland we find in the head branches of the Flint Steel River the first rock exposures which consist of a very large succession of grayish colored, somewhat micaceous, fine-grained sandstones, cleaving into thin, even flags with interstratified, more argillitic slate beds. In the lower part of the series several beds of coarse conglomerate of brownish color are found interposed. Still lower a large conglomerate belt succeeds which is not less than 600 or 800 feet wide; the cuts of the lately built railroad from Rockland to Ontonagon have fairly exposed this belt; its strata dip under an angle of 45 degrees to the north.

The gray colored, flaggy sandstones with argillitic seams are considered to be the equivalent of the strata of the Nonesuch mine 20 miles farther west; we see exposures of them all along in the intermediate space, and also eastward south of Maple Grove the same series of rock beds is found denuded in most all the ravines of the branches of Flint Steel River. South of the large conglomerate belt follow various amygdaloidal and compact diabase belts, then comes a large belt of quarto-porphyry which is well exposed in the N. W. ¼ of Sec. 9, T. 50, R. 39, next to the wagon road from Rockland to Ontonagon, about a mile north of the first mentioned village. On the railroad half a mile farther west this belt is not well exposed; only a few ledges of a compact, fine-grained, somewhat banded rock of dark purplish brown color seem to represent it there.

The porphyry of this belt varies in different shades of purplish brown; some portions are full of larger segregated crystals of feldspar and glassy grains of quartz; in others scarcely any quartz grains occur, while feldspar is abundant; still other portions inclose no larger crystals and are a homogeneous, fine-grained mass, with dull, conchoidal fracture. Under the microscope the groundmass is composed of a minutely granular mixture of turbid molecules which seem to be feldspar, and of a transparent, interstitial substance which is probably quartz; no really isotropic matter is between, but within this mass a large number of irregular, dark colored, impellucid granules are dispersed, which on the edges exhibit a slight permeability for the light; in addition, we find inclosed green dichroic hornblende prisms, most of them fractured or rounded on the edges, and the before mentioned larger feldspar crystals and quartz grains. A specimen of the homogeneous, fine-grained kind of the rock, with no porphyritic segregation of feldspar crystals exhibits a truly fragmental structure, consisting of small, sub-angular fragments of turbid and iron-colored feldspar, of grains of quartz and of hornblende fragments cemented together. South of the porphyry belt an amygdaloid belt is exposed on the railroad, which consists of a brecciated intermixture of irregular, fragmental, amygdaloid masses cemented by abundant sedimentary interstitial seams of drab color, gritty and somewhat porous, absorbent; it has some resemblance with the Ashbed of Eagle River. Farther south a large belt of dark colored, compact diabase follows; part of it is very fine-grained like the Ashbed diabase, another part has the coarser grain of the ordinary diabases and carries olivine.

The interval from this belt to the hills of the National and Minnesota mines, about a mile in width, is filled with an alternating succession of compact diabase belts, amygdaloid and conglomerate or sandstone seams, of which conglomeratic seams six are known to occur, some of which are 50 feet wide, others only 12 or 15 feet.

The amygdaloids carry some copper in their exposures in the numerous ravines running down to the Ontonagon River, but only one of the belts next above the hanging wall of the National mine has been found rich enough to be profitably mined. The miners call this belt the north vein of the National mine. It is purplish brown colored, quite hard, sometimes even flinty in its fracture, its amygdules are filled with calcspar, prehnite, epidote, quartz, associated with copper, but the largest portion of copper in bulkier masses occurs in epidotic portions of the rock belt which intersect it in all directions. The underlying diabase belt, about 120 feet in thickness, is dark colored, middling fine-grained, or also coarser-grained, olivine-bearing, which latter mineral is partially changed into a purplish, iron-colored, micaceous mineral like rubellan. Numerous irregular, pseudo-amygdaloidal spaces in the rock masses are filled with the often before mentioned green aphanitic mineral resembling serpentine.

Beneath this belt and an underlying coarse conglomerate belt, a seam sometimes only a few inches wide, other times expanding to the width of three feet, and locally into much larger pocket-like dilatations, is composed of fragmental diabase masses, often covered with a smooth, slickenside coating, wedged in between a seamy compound of dark green serpentines and fibrous chrysotile-like mineral in intermixture with calcspar, prehnite, laumonite and epidote and red feldspar, besides quarts, in which seam, called the south vein of the mine, the copper is intermingled in ramified, hackly, laminate masses, and often in larger ponderous concretions, many tons in weight; the largest of these found in the Minnesota mine weighed 500 tons.

In the National and Minnesota mines transverse fissure veins were met with, during the progress of the work, which at the crossing with the other copper-bearing belts were found very rich in copper and have been followed by drifts.

The conglomerate belt underlying the south vein of the National mine is about 20 or 30 feet thick; its lower portion is a fine-grained, brown sandrock. The copper masses of the above mentioned larger size often are partially imbedded within this conglomerate, as most of the metal has accumulated on the foot-wall side of the vein, and its pocket-like expansions intrude the underlying rock belt. Many of the blocks of conglomerate found in the burrows contain a considerable amount of malachite and red oxide of copper within the interstitial seams of the cement. Beneath the conglomerate belt an amygdaloid belt follows next; farther south a succession of compact and amygdaloidal diabase beds, amounting to over a mile in thickness, follows, which composes a second range of hills south of the hills of the National and Minnesota mines. The south slope of this second range sinks down to a drift plateau which borders the channel of Ontonagan River, and no more of the copper-bearing rocks is visible at the surface. All the rock ledges seen in the valley, if an erosion has laid them bare, are horizontal Silurian sandstone ledges. This belt of Keweenawan rocks beneath the Minnesota mine has, to some extent, been explored with the diamond drill by this company, but a much better knowledge of it we obtain by a great number of mines opened in this series east of the Minnesota mine.

We learn by them that five copper-bearing, amygdaloid belts, or in the miners' language, veins, occur south of the Minnesota belt, which all have received names from the places where such a belt has been principally mined. The first belt south of the Minnesota mine is the so called Knowlton vein, worked by the Knowlton mine and by the adjoining Mass mine. I could not ascertain the exact distance between the two belts, but guessing at it from the distance of the old shafts opened in the Minnesota vein, north of the Mass mine, it must be about 2,500 feet. The distance of the other veins south of this has been accurately measured in a tunnel of the Mass mine driven across the range enclosing all of them; the length of the tunnel is 1,400 feet. One hundred and twenty feet south of the Knowlton vein occurs the Mass vein; 290 feet further the Champion vein is intersected; ninety feet further is the Ogema vein, and 260 feet south of it is the Evergreen vein. All these copper-bearing belts are parallel with the stratification of the range, not sharply defined from the surrounding rock masses by a demarkating line like a fissure vein is from its walls, and also the copper is not confined to the space practically considered as the vein, but occurs often in the adjoining rock masses less copiously. The vein-rock of the Mass mine is a rather hard, dark brown amygdaloid, interwoven with seams of calcspar, epidote, quartz, prehnite, and red feldspar. The copper is partly inclosed within the amygdules, but more of it occurs in heavier masses surrounded by calcspar, epidote and quartz, in seams intersecting the amygdaloid. Not rarely also porcelain-like datolite masses inclose the copper in well formed, perfect crystals. The Mass mine, like the adjoining Ridge mine and Adventure mine, is renowned for the occurrence of fine specimens of silver associated with copper. The Ridge mine, formerly the most important on the range, is at present almost abandoned. Its first shafts were opened in the Champion belt; later the Evergreen belt was principally mined on the location. The vein-rock of the Ridge mine is partly an epidotic mass, partly is composed of calcspar, quartz and red feldspar, which form a network of seams intersecting a hard amygdaloid; the interstices between the agglomerated spar and quartz crystals are often filled with snow-white, porcelain-like datolite; also the copper fills the interstitial spaces between these minerals, often in heavy masses.

The Adventure mine, next east of the Ridge mine, is for a good while abandoned; the work done there is scattered over different places, indicating that the copper was found in limited, pocket-like accumulations. The vein-rock in some of the openings is full of druse cavities, lined with fine crystals of calcspar, quartz, epidote, and red feldspar, in rhombical, salmon-colored crystals, which look more like stilbite than feldspar, but their hard fusibility and resistance to the action of acids readily distinguishes them from this mineral.

East of the Adventure mine, on the same range, the old Bohemian mine has lately been opened under the name of Belt mine, and a large stamp mill was built a mile from the mine in the valley of Fire Steel River.

The conspicuous bluffs on the location inclose the five copper-bearing belts intersected in the tunnel of the Mass mine. The shaft presently opened on the south side of the bluffs is sunk on the Champion vein, a purplish gray-colored amygdaloid, of crystalline grain with amygdules of calcspar and epidote, and intersected by numerous epidotic seams, porous or compact, in intermixture with spar, quartz, prehnite, feldspar, etc.; the inter-mingled copper occurs mostly in coarse, hackly masses; less of it is interspersed in grains and leaflets. On the north side of the bluffs new shafts have been opened in the Knowlton vein, following the inclination of the seam, which dips under an angle of 35 degrees north.

The belt is not well defined from the diabase in the hanging and on the foot-wall; the mined portion of the seam, in which most of the copper is concentrated, is between three and four feet wide, but locally becomes much wider. The vein matter is an amygdaloidal, brown and green mottled, brecciated rock, with cementing seams of spar, quartz, epidote, and much of the aphanitic, soft, green, serpentine-like mineral. The copper is inclosed in heavier sheets and in delicate leaflets, coating over the slickensided surface of the innumerable capillary fissures dividing the rock mass into small segments, rapidly disintegrating on exposure.

The other copper-bearing belts in the bluff are at present not yet opened. The old Bohemian mine had done some little work in the most southern Evergreen belt and in the Ogema belt.

The rock sent to the stamps, inclusive of the coarse mass-copper picked out at the mine, yields from three to three and three-fourths per cent of copper. At the time of my visit, one Ball stamp, eighteen inches in diameter, was in operation, capable of pounding 200 tons of rock daily; a second similar stamp is being put up, and will soon be put in operation.

On the north side of the Belt location, at the distance of about one half a mile, old shafts and large burrows show that in previous years much work had been done in the belt corresponding with that of the Minnesota mine. The continuation of the Copper Range east of the Belt mine, in direct connection with the Portage Lake range, I have not specially examined; a large number of abandoned mining locations are encountered on this part of the range, some of which are reported to me as at one time very promising. Also the part of the Copper Range west of Rockland, on to Lake Gogebic, is, on its south side, one continuous string of mining locations, all of which are presently abandoned. These western mines worked nearly all in fissure veins, while the eastern almost exclusively followed seams parallel to the bedding of the range. The Forest or Victoria mine, occupying a very conspicuous position on the top of a hill, on the west side of Ontonagon River, three miles west of Rockland, is not opened in a fissure vein, but follows a belt supposed to be the equivalent of the Evergreen belt; an epidotic, amygdaloid rock on the burrows, contains considerable amount of copper, and it is said that in the days the mine was worked some large masses of copper were taken out of it.

Short distance west of the shafts, on the location, a conglomerate belt, underlying the amygdaloid of the mine, crops out on the roadside. The dip of the strata at the mine is under an angle of from 60 to 70 degrees northwestward.

South of the location, towards the west branch of the Ontonagon River, a succession of alternating, compact diabase belts and amygdaloid beds, amounting to over 1,200 feet, is well exposed; the lowest beds of the series project in high vertical bluffs along the narrow river valley, the base of which is surrounded by a terrace of drift deposits or by talus of the decomposing cliffs. The river bed is carved into a large succession of horizontal Silurian sandrock beds, over which the water flows in stairlike, small cascades, which, as is visible in time of low water, have excavated in the beds a great number of large and small round pot holes. The drift masses and the talus prevent the exposure of the discordant contact of the sandstones with the trappean rocks, but the intervening covered space is often so narrow that it would require not a great amount of digging to lay it open. West of the Victoria mine, I mention, among the great number of others, the Windsor, Trap, and Norwich mines, joining together, which mined epidotic fissure veins, intersecting the very high bluffs of trappean rocks facing the valley of the west branch of Ontonagon River. At the base of these bluffs, a soft, crumby amygdaloid crops out, and beneath it a conglomerate belt, the thickness of which I could not see, as the lower part of the bed disappears under drift deposits which cover the bottom of the valley in which, in certain places, the horizontal Silurian sandstones have become denuded by erosions of the river.

Farther west on all the numerous mining locations formerly established there thick underbrush has grown up, so that no chance is left to gather much information by running over the places. In one place, only a mile east of the outlet of Lake Gogebic, in T. 49, R. 42, Sec. 35, a peculiar rock seam of great width is seen interstratified between diabase belts of the ordinary kind composing the range. This is a fine-grained, compact rock, pale red and greenish yellow speckled. Macroscopically it consists of a turbid, granular, feldspathic mass, greenish colored by intermingled epidote, in which globular concretionary masses of rosy color with fibrous concentrically radiated structure are thickly embedded; also distinct crystals of quartz were seen inclosed. Under the microscope much more of interstitial quartz masses is discernible mingled with the groundmass; the presence of some carbonate shows itself by slight effervescence of the rock treated with acid; the red fibrous mineral is not attacked by acids, and fusible with difficulty on the edges. In all probability is the rock described by Foster & Whitney's report, page 71, the same. Their specimens were found in Sec. 33, T. 49, R. 43.

The general character of this rock belt is in close relationship to that of the quartz-bearing porphyry, of which a very large belt, locally over a mile in width, forms in this township north of the trap range a separate parallel row of high hills, presenting towards the valley of Cascade River, a tributary of the Ontonagon, high vertical escarpments. The trap range has here a width of about four miles; its north side slopes gently down toward the before mentioned valley. The strata dip under an angle of about 50 degrees to the northwest.

The porphyry belt composing the range on the north side of the valley of Cascade River apparently reposes conformably on the diabase belts forming the range on the south side. I traced this porphyry belt without interruption of the exposures across the north half of T. 49, R. 42; Secs. 7 to 12 are almost exclusively underlain by this rock. In the adjoining eastern township the belt is continued, trending in a more northeastern direction than before when its course was almost clue east and west. In the line of strike of this porphyry belt we find farther east in T. 50, R. 41, four miles north of the Norwich mine on the road to Ontonagon, a series of rock beds exposed which differ in character from the just described porphyritic belt, being of a sub-porous, gritty nature, with dull fracture, devoid of disseminated quartz grains and only sparingly inclosing small feldspar crystals.

Under the microscope this rock consists of a minutely granular mass of red colored turbid feldspar sparingly intermingled with lobate interstitial masses of quartz and crowded with dark colored, ferruginous granules, dustlike disseminated, and also aggregated into small clusters; likewise distant grains of augite are observable. Most likely also the previously described outcrop of typical quartz-porphyry, a mile north of Rockland, is occupying a similar horizon with these western porphyries. The porphyry bluffs in T. 49, R's 42 and 41, are composed of bulky rock masses showing no stratification, but being intersected by innumerable irregular cleavage cracks, making the hard rock very brittle. The color varies in different shades from gray to brick-red and to dark liver-brown.

The very fine crypto-crystalline groundmass with flinty fracture is thickly studded with large reddish or also whitish colored feldspar crystals, besides obtusely angular crystals of glassy quartz which appear black in reflected light. The quartz frequently incloses besides air bubbles and small microlites, also detached lumps of the surrounding groundmass, and is intruded by club-shaped prolongations of the same which are in connection yet with the main mass. The feldspar crystals are usually intersected by a network of linear seams infiltrated with rusty, ferruginous matter; not rarely also irregular, hackly masses of transparent quartz occupy the interior of the feldspar crystals, probably secondary depositions replacing the feldspathic substance. The groundmass itself appears under the microscope as a curdled, reticulated intermixture of turbid, reddish colored aggregations of feldspar granules with an interstitial network of quartz; a fluidal structure indicated by darker colored, wavy lineation is often observable. Locally portions of this porphyry belt have a completely crystalline, granite-like structure consisting of an agglomeration of larger sized red feldspar crystals in intermixture with colorless, transparent, irregularly-shaped quartz masses, which frequently inclose delicate apatite prisms, and with dark, greenish black colored crystalline molecules, consisting of augite or paramorphic products of it in association with magnetite granules. This granite-like, structure is peculiar to eruptive rocks; the eruptive nature of granitoid porphyry is further proved by the occurrence of analogous rock masses in dyke form cutting across the lower beds of the Keweenaw group, as we find them for instance in the vicinity of Duluth, Minnesota.

The inclosure of small isolated lumps of the porphyritic groundmass within the quartz crystals segregated in it and their intrusion by club-shaped prolongations of the surrounding felsitic mass is another argument for the igneous origin of the porphyry, as this fact is only reasonably explainable by assuming the formation of the quartz crystals within a molten mass of which accidentally portions became enclosed while the masses were liquid. The fluidal lines so often observed in the porphyries are a farther proof of their once molten condition. Considering the great resemblance of the felsitic rocks which form another northern belt in the Porcupine Mountains, with this southern belt, we cannot otherwise than suggest the igneous origin of that, although it exhibits not as clearly the marks of an eruptive rock. The felsites of the Bohemian Range on Keweenaw Point are perfectly identical with the felsites of this north belt of the Porcupine Mountains, whose identity with the southern quartz-porphyry belt is farther evinced by a direct connection of the two belts in a horseshoe curve as it is represented on the map of Prof. Irving's work.

The porphyry belt trending across the north part of T, 49, R. 42, is, on its north side, succeeded by diabase and amygdaloid belts; they dip under a steep angle northwest, like the porphyry. Good exposures of these rock beds are found in the ravines of an east branch of Iron River, next to the southeast corner of Sec. 12, T. 49, R. 43. The diabase is middling fine-grained, dark blackish colored; the amygdaloids have their cavities filled with calcspar, laumonite, delessite, prehnite, and quartz; an impregnation with copper I did not observe.

A mile north of the mentioned place, near the quarter-post on the south line of Sec. 1, projects an isolated knob of diabase, which is the last rock exposure seen on the trail from there to the Nonesuch mine. The rock is very fine-grained, with dull, earthy fracture; its color is dark purplish brown; dip northwest.

In the bed of Iron River, at the crossing in Sec. 25, T. 50, R. 43, a large amount of angular slabs of the sandrock of the Nonesuch group is found, indicating the intersection of this belt by the river at no great distance up the stream. On Little Iron River at the Nonesuch location, this sandrock formation named after the mine, is cut through by the river in a deep ravine, in which about 400 feet of strata are denuded, dipping southeast under an angle of 30 degrees. This rock series continues westward along the valley of Little Iron River, retaining its southeastern dip. The high hills bordering the north side of the river are composed at the base of diabase and amygdaloid belts dipping northward; their top part is formed by felsitic rocks identical with the felsites of the Bohemian Range on Keweenaw Point. This felsite dipping north in conformity with the trappean beds forms an immensely large belt extending eight miles westward from the mine in a width of more than two miles. Thence the rock belt makes a curve towards the south, in which direction I have not yet examined it. The northern extension of the felsite belt can be most advantageously examined by following the north line of the township from the top of the hill at the Nonesuch mine westward, as it corresponds pretty near with the south margin of the crest of the mountain chain on which the strata are almost without an interruption exposed in vertical bluffs. The northern part of this felsitic rock belt is best examined in the main head branch of Carp River, which drains the north slope of this range of hills and has carved a deep ravine into this belt and the succeeding higher strata.

Ascending the hill northwest of the Nonesuch, we find this terminal part of the range entirely composed of stratified layers of diabase amounting to great thickness, which dip under a moderate angle northeast. The larger portion of this series of beds of diabase has a reddish brown color, as the abundantly intermingled magnetite granules have almost completely changed into red oxide; all of the beds are fine-grained, some very compact, others sub-porous, which latter are lighter colored, often dotted with rounded specks of pink color, which give the rock the appearance of an amygdaloid, but have actually discolored only portions of the mass in the same mode as we see the red sandstones of the Sault Ste. Mary's Canal variegated by discolored round specks.

Under the microscope is found in all the examined specimens olivine quite freely disseminated, partially altered peripherally into a purplish colored substance. The augitic constituent of the rock is likewise altered and has partially lost its clear transparency. A porphyritic segregation of larger feldspar crystals in the fine-grained groundmass of the diabase is frequently observed.

The felsitic rocks which are incumbent on this diabase belt are first met with a mile west of this promontorial point in the north part of Sec. 3, and thence uninterruptedly through Secs. 4, 5, and 6 of T. 60, R. 43. As before stated, the rock is the same brittle, compact, reddish colored, silico-feldspathic mass which composes the felsite belts of the Bohemian Range on Keweenaw Peninsula; portions of the belt have the structure of a breccia; a banded laminated structure is rarely observable in these eastern outcrops.

Thin sections of the rock appear under the microscope as a uniform microcrystalline curdled intermixture of reddish colored, somewhat turbid feldspar with interstitial quartz masses. Nearly always, dark impellucid ferruginous molecules of irregular form are found more or less copiously disseminated. In some portions of the rock, irregular dots composed exclusively of quartz grains clustered together, interrupt the homogeneity of the crystalline magma. The quartz usually incloses many microlites and air bubbles with a libelle,* capillary fissures of the quartz are sometimes infiltrated with purplish color, and here and there transparent grains clustered together are found scattered, which seem to be augite. No isotropic parts are observable except basal sections of quartz. In Sec. 4, at the base of the felsite bluffs, a fine-grained blackish colored compact diabase crops out in association with a coarse conglomeratic or brecciated mass of amygdaloid blocks cemented by abundant sedimentary material of purplish brown color with dull earthy fracture, exactly like the amygdaloid breccias so frequently seen on the shore of Bête Grise Bay. Also further west in many places diabasic rocks can be seen exposed beneath the bluffs of felsite, as for instance on the north line of Sec. 7, in the fork between two creeks, where a porphyritic diabase occurs with copiously interspersed large red feldspar crystals in the minutely crystalline blackish ground-mass. This rock is very similar to the porphyritic diabase which forms the hanging of the felsite of Bête Grise Bay oil the north line of Sec. 35, T. 58, R. 28.

[*Dr. Rominger means that the quartz, beside inclosing air-spaces, also incloses liquid in which there is a "libelle," i. e., a bubble of air or gas. L. L. H.]

Near the west line of T. 50, R. 43, at the southwest corner of Sec. 7, the sandrock strata of the Nonesuch group, dipping under a steep angle southeastward, are largely exposed in the branches of a creek and by an exploratory shaft sunk there in search of the copper-bearing seam, which was discovered here equally rich in copper as at the Nonesuch mine.

Ascending higher on the hillslope we find the felsite next succumbent to the sandrock formation, but the massive condition of the felsite does not allow one to determine the nature of the contact, whether it is discordant or conformable, but on top of the range and further north the dip of the felsite is clearly seen to be in a northern direction. High knobs of felsite occur on the line between Secs. 1 and 2, of T. 50, R. 44, and on the south line of Sec. 2. The rock is here reddish brown colored, very compact, of flinty fracture, but locally a contorted well laminated structure is observed. South, on the line between 11 and 12, the rock has a purplish gray, almost whitish color, is gritty, rather porous, and encloses a great number of disseminated small crystals of iron oxide of black color with great lustre; this rock contains also numerous small druse cavities filled with quartz crystals; rarely also violet colored little cubes of fluorspar are enclosed.

The northwest corner of Sec. 11, T. 50, R. 44, is on top of a high knob of compact red felsite. Crossing the valley of Little Carp River on the line between Secs. 10 and 3, we find an opposite high knob composed of very coarse crystalline olivinitic diabase resembling the coarsest varieties of greenstone from the height of the bluffs at the Cliff mine.

A fine view of Lake Superior opens on the summit of this hill. West of it no more felsite exposures are observable; the felsite belt bends here southward, following the valley of Little Carp River in which direction I did not follow it. The north side of the described felsite belt and a series of incumbent strata are well exposed in the main head branch of Carp River in Sec. 30, T. 51, R. 43.

Ascending from the Carp River road the ravine-like bed of the creek we see first a large conglomerate belt exposed dipping north; the lower strata of this belt are a compact fine-grained dark brown colored sandrock. Beneath it follows a belt of diabase about 200 feet wide; part of the belt is in compact layers; the greater portion has an amygdaloidal structure with prevailingly epidotic arnygdules; certain amygdaloidal seams are brecciated, recemented by a fine-grained compact sedimentary mass. The next lower stratum is another conglomerate or rather breccia belt, consisting of the same material as the former, but the fragments are angular, very firmly cemented.

Then comes another series of diabase rock beds, the upper ones gray colored, the lower ones of reddish brown color, fine-grained with dull earthy fracture; some amygdaloidal seams, likewise of red color are found interstratified between the compact beds, the amygdules filled with epidote and quartz. Below this quite large series of red colored diabase beds follows the felsite in compact flinty brick-red colored, tolerably well laminated beds which are with difficulty distinguished from the overlying red diabase; on microscopical examination, however, the difference between the two rocks is quite obvious.

The felsite beds give occasion for a cascade about 25 feet high, above which constant exposures of the same rocks are seen in the creek bed for half a mile further on, as far as I went. Returning to the road and descending to Carp Lake, I found on the north side of the first mentioned conglomerate belt layers of compact diabase and interstratified amygdaloid seams, all dipping north under an angle of about 35 or 40 degrees. After crossing the river at the location of the old stamp mill, now destroyed by fire, we are at the foot of high vertical bluffs formed of fine- grained thinly bedded brown sandstones amounting to a belt several hundred feet in thickness. The top of the bluffs is formed by an overlying large belt of diabase interstratified with amygdaloidal seams. The upper strata of the sandstone belt on the line of contact with the incumbent diabase are locally richly impregnated with copper, which strata were mined in connection with a transverse fissure vein intersecting the strata in this locality. The vein rock is calcspar in brecciated intermixture with fragments of the sandrock and diabase. The results of this mining were never satisfactory, and since more than 15 years, work has been abandoned there. Several other abandoned mining locations are four and five miles further west in the continuation of these high bluffs. These latter mining companies followed epidotic fissure veins charged with copper. The mining was done by driving horizontal drifts into the base of the diabase bluffs, which there sink down to a lower level in the valley than they do up at the Carp Lake mine.

A mile east of the Carp Lake mine the Cuyahoga mine worked one of the amygdaloidal belts interposed between the series of diabase rocks composing the summit portion of the shore range. The north slope of these hills is formed by a very large sedimentary belt several hundred feet in width, whose lower portion is a coarse conglomerate; the upper consists of brown colored sand-rock beds with occasionally interlaminated narrower seams of coarse conglomeratic nature; the dip of these beds northward has an inclination from 30 to 35 degrees; the entire shore line from Union Bay to the mouth of Presque Isle River is formed by this belt. Numerous spar veins are seen to intersect it, but none of these was found to be copper-bearing or otherwise metalliferous. Many of these sandrock beds are plainly ripple-marked on the surface.

At the Union mine this sandrock belt forms the hanging of the amygdaloid belt mined in that locality. The amygdaloid makes part of a belt of diabasic rock ledges amounting to a thickness of from 300 to 400 feet, beneath which again a large belt of sandrock several hundred feet in thickness occurs, supposed to be the equivalent of the sandrock in the bluffs of the Carp mine. The bed of Union River presents an uninterrupted cross-section through the mentioned series of rocks. Of the succeeding strata southward, between Union mine and the Nonesuch location, the densely forest-covered condition of the country allows not often an exposure to be seen. A large belt of a red colored speckled amygdaloid, dipping only slightly inclined northward, is observable in the bed of a creek on the roadside between the two mines; the densely crowded amygdules are filled with laumonite and calcspar. Parts of the belt are solid, another portion is a breccia with an abundance of sedimentary cement. The very frequent occurrence of such brecciated amygdaloid belts in all horizons of the group, suggests the sub-marine overflow of lava masses and the recementation of their vesiculous bursted and shattered superficial crust by sediments, after sufficient refrigeration and subsidence of ebullition.

The Nonesuch group next incumbent on the before described wide belt of brown sandrock and conglomerate beds which forms the north slope of the shore range between Union Bay and the mouth of Presque Isle River, locally reposes conformably on these strata, but in other places it is found in evident discordance with them and the other older members of the group. At the Nonesuch location this series of beds, as far as exposed, amounts to 400 or 500 feet of strata, dipping southeast under an angle of 30 degrees, while the closely adjoining trappean rock beds dip to the north; the immediate contact is not visible.

The group of strata seen there consists most of thinly bedded gray or bluish colored micaceo-argillitic sandrock ledges interstratified with slaty argillitic seams and with some thicker, more compact seams of sandstone, or also of a coarse conglomerate rock principally composed of porphyry pebbles. Single pebbles of porphyry are found scattered through all the beds.

Within this succession a seam of arenaceous rock about three or four feet wide is found richly impregnated with fine particles of metallic copper; more rarely heavier sheets of copper fill fissures in the ledges.

The percentage of copper in this seam is amply large enough to compare favorably with other profitably mined rock seams, but the fine comminution of the metal causes in the washing process a great loss, as the scaly particles float away with the sand, and several experiments to save this fine copper by chemical treatment of the stamped rock proved so far to be failures in economical respect.

North of the Nonesuch location, following the Little Iron River downward, the strata soon disappear under heavy drift masses, but reappear again about two miles from the shore on this creek and on Big Iron River. East of the Nonesuch mine the belt continues to be exposed for about three miles and there in another mine, the White Pine location, the cupriferous seam is found to be equally rich in copper; also on Mineral River this cupriferous seam has been discovered in several localities.

Following the bed of Iron River from the Nonesuch mine, as before stated, the strata soon disappear under drift masses; about three miles down stream a belt of brown sandstone, trending east and west, is found crossing the river bed, dipping north under an angle of 50 degrees. The exposures continue for 100 steps, then at once without an interruption of the outcrops the sandrock beds apparently the same as the former trend northeast and southwest, dipping southeast under a much flatter angle, not over 25 degrees.

Two hundred steps further down, the same sort of brown sand- stone beds has again an east and west trend and steep northern dip. After a short distance the outcrops disappear for the space of 145 steps along the river bed, then again the brown sandstones are largely exposed, trending northeast and dipping southeast under an angle of about 30 degrees. Several conglomerate seams are in this place interstratified with the sandrocks, amounting to 400 or 500 feet of strata. The lowest beds seen there resemble the cupriferous stratum of the Nonesuch mine. Further on, an abrupt change in the quality and position of the rock beds occurs, they trend east and west and dip north, first in very steep inclination, then gradually flattening their dip. The color of the very even-bedded arenaceous flagstones is bluish gray; onward the same beds continue, becoming almost horizontal with slight dip to the southeast; low falls about five feet high occur in this place, in the N. W. ¼ of Sec. 24, T. 51, R. 42. Some distance below, the strata dip under an angle of 15 or 20 degrees east, trend north and south, close to the north line of the section; the beds here are blue slate-rocks; they continue to be exposed for a long distance downward, retaining the same dip and strike, and amounting to a succession of several hundred feet of beds. Near the so called Scranton mine the strata dip southeast under low angle; lower down near the lake shore the same beds dip northwest very flat, locally almost horizontally. Underlying these beds we observe near the shore reddish brown colored sandstones, which are evidently the same as those exposed on the shore of Union Bay.

As my observations of this group along the valley of Big Iron River and Mineral River have been described previously in the third volume of the report, on pages 152 to 159, I refer the reader to them in order to avoid repetition.

On the east side of Iron River we find incumbent on the Nonesuch series a group of brown colored sandstones much more quartzose in composition than the darker tinged sandrocks of Union Bay, and not near as steeply inclined as they are; their dip is usually not over 15 degrees northward, and often less. This group of sandrocks borders the shore part of the country in a wide belt from Iron River to Portage Canal entry and farther north. They are the youngest deposits of the Keweenaw group, and their almost perfect resemblance to the so called eastern sandstones almost irresistibly impresses one with the idea of the uninterrupted succession of the Silurian sandrocks to the latest, considered to be Keweenawan. The probability of this is somewhat shaken by the structural features observed near the mouth of Montreal River and westward. The very large series of sandrocks exposed near the mouth of Montreal River in almost vertical position is found land-inward to be succeeded by a belt of gray sandrocks and slaty beds traceable from the mouth of Black River to the place where it intersects Montreal River, which is the analogon of the rock series of the Nonesuch mine.

The group of beds between this Nonesuch belt and the shore occupies the same relative position as the almost horizontal beds constituting the shore belt between the mouth of Iron River and Portage Canal entry, their analogy should therefore be expected, but by their fiat dip and by their lithological character they approach much nearer to the horizontal sandstones of the Apostle Islands, which abut in great discordance against the sandstones of Montreal River, must therefore be younger, and great disturbances must have occurred between the deposition of the two.

But this unconformity is not necessarily a proof of a general break in the events and of a great lapse of time between the deposition of the Montreal River beds and those of the Apostle Islands. It proves only for this locality an excessive disturbance which caused discordance between the already formed strata and those later deposited, while not a great ways off towards the east the disturbance was more gentle and the deposits in these places without suffering an abrupt break continued to form there without interruption, gradually lessening their inclination in the same measure as the upheaval subsided.

Taking in consideration the topographical position of the Nonesuch strata in the Portage Lake country and on the Ontonagon River and their distance from the shore where the nearly horizontal beds crop out, we find ample space left not only for the Montreal River sandstone series in its greatest display but also for an intermediate succession of strata linking these by gradual decrease in the dip with the horizontal sandstones on the shore.

The deeply drift-covered condition of this intervening space prevents the actual observation of this suggested uninterrupted succession, but no facts are known positively contradicting such suggestion of an uninterrupted formation of sediments in the same ocean basin from the time of the deposition of the Montreal River sandstones to the deposition of the so called western sandstones.

The similarity of the sandstones between Iron River and Portage Canal entry with the rocks composing the Apostle Islands is so great that I think it quite improbable to suppose a radical change in the conditions and a great lapse of time intervening between their deposition.

The proximate age of the upheaved upper Keweenawan rocks with the horizontal Silurian might also be inferred from the circumstance of the occurrence of small quantities of bituminous oil in the Nonesuch beds, as the first sign of organic life which henceforth developed itself more prolifically in the Silurian rocks. The sometimes steeply inclined position of the Nonesuch beds and their other times almost horizontal position observed in the Iron River district, shows clearly that local disturbances occurred at that time which could effect a discordance of contemporaneous strata, as we find it near Montreal River.

(6) GOGEBIC LAKE.

It remains yet for me to give a description of the copper-bearing rocks west of Gogebic Lake, but I have so far examined that formation only occasionally on its line of contact with the iron-bearing rock series.

The apparently conformable superposition of these diabasic overflows on the Huronian strata has been previously mentioned with the remark that different, higher or lower, beds of the latter group are found in contiguity with the diabases, which proves that an erosion of their surface must have occurred before they were covered with these overflows.

The majority of the diabasic rocks in contact with the iron-bearing strata have a porphyritic structure, consisting of a minutely crystalline groundmass in which large plagioclase crystals are abundantly dispersed in clusters. Copper is rarely found associated with these rocks, and then only in small quantities.

The very interesting Isle Royale likewise could not be described in this report, as I have not far enough advanced in its examination during the past season to be prepared for publication of the results.

CROSS-SECTIONS.

On pages 112 and 113 of the foregoing report I have stated in foot notes that sections of Tamarack shafts, Nos. 3 and 4, and of the Calumet and Hecla mine would be substituted for the record mentioned by Dr. Rominger, which at the time the foot notes were inserted was not in my hands. The Tamarack record is complete to the latter part of March, 1894, and with the Calumet and Hecla record gives a cross-section of 8,400 feet horizontally, which represents 5,100 feet measured at right angles to the original surface of the beds. The distance between the Red Jacket shaft of the Calumet and Hecla mine and Tamarack No. 3, is about 1,300 feet. The observations in the two mines having been made by different persons, it is not strange that trap and amygdaloid beds do not show a closer correspondence in the two vertical shafts, even if allowance be made for local irregularities. On the other hand, the same beds in different shafts or cross-cuts of the same mine show a noticeable persistence.

A comparison of the conglomerate beds shown in these cross-cuts with those figured by Marvine, in Volume I of these reports, makes it probable that we have here, next above the Calumet conglomerate, the Allouez conglomerate, Marvine's No. 15, as well as his Nos. 16 and 17, all of which, at Calumet, are thicker than at Eagle River. Marvine's bed No. 14, the Houghton conglomerate, is wanting in both mines, and his No. 12, the North Star conglomerate, which would occur next below the Calumet conglomerate, is not found in the Calumet and Hecla Mine. The conglomerate beds being nearer together than at Eagle River, show a convergence towards the southwest, *i. e.*, a thinning of the intermediate eruptives, which confirms Marvine's observations.

L. L. HUBBARD.

Houghton, May, 1894.

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.