GEOLOGICAL SURVEY

OF

MICHIGAN

1880.

GEOLOGICAL SURVEY OF MICHIGAN.

UPPER PENINSULA

1878–1880

ACCOMPANIED BY A

GEOLOGICAL MAP.

VOL. IV.

PART I. MARQUETTE IRON REGION.

PART II. MENOMINEE IRON REGION.

BY

C. ROMINGER

STATE GEOLOGIST.

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UNDER THE DIRECTION OF THE

BOARD OF GEOLOGICAL SURVEY.

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ERRATA:

Page 114—line 23, read "the iron-bearing" instead of "this."

" 173—line 24, read "east line" instead of "west line."

" 174—line 27, read "east line" instead of "west line."

" 175—line 5, read "not far" instead of "north, far."

" 220—line 15, read "substance" instead of "susbtance."

" 223—line 6, read "of the Quinnesec ore-formation" instead of "underlying the Quinnesec ore-formation."

" 236—line 13, read "Selden" instead of "Sheldon."

PART I.

MARQUETTE IRON REGION.

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PART II.

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To the Honorable the Board of the Geological Survey of the State of Michigan:

GENTLEMEN:

Having been asked by your honorable body to furnish a statement of what has been accomplished by the geological exploration of the State since the beginning of the Survey, and also to designate what in my opinion yet remains to be done, I have the honor to submit the following for your consideration.

The general structure of our State, of the Lower as well as the Upper Peninsula, has been as thoroughly examined as time and circumstances enabled.

Of the Lower Peninsula and of the eastern part of the Upper (which portions of the State are underlaid by horizontal strata of the Silurian, Devonian, and Carboniferous periods) we have acquired sufficient knowledge for all practical purposes. The greater part of these districts is deeply covered with drift deposits which hide the older rock-beds; but from local exposures, from borings and other artificial denudations of these older rocks, it becomes possible not only to ascertain the local extent of each of these formations, but also to positively designate what kinds of minerals are found in each of these districts, and to indicate where they may be found in places in which they have not yet been discovered.

The case is altogether different with the western part of the Upper Peninsula, the structure of which consists of the oldest known rocks, partly of a sedimentary and partly of a volcanic origin.

By volcanic action these sedimentary rocks have not only been lifted from their horizontal position into all degrees of inclination, and in some places even completely overturned, but have also been considerably altered so as to again resemble, more or less,

the volcanic rocks from the transformations of which they originated.

While the relative age of the younger horizontal sedimentary rock-beds may be determined without difficulty by the order in which they are superposed and from the organic remains peculiar to each of the successive groups of beds, in the examination of the older upheaved sedimentary rocks, we can no longer rely with any degree of safety upon their order of succession, as their relative position is often changed and even completely reversed by plication of the beds and by faulted dislocation. We do not find fossils in them to guide us in the discrimination of one rock from another; we can only resort to the nature of the rock itself, and this is a fallacious criterion, as the rocks in question are remarkably uniform in their composition and resemblance; while on the other hand there are local differences in molecular structure and degree of metamorphosis which cause analogous beds to differ widely in appearance. I thus briefly allude to these difficulties, that hinder the speedy recognition of the geological structure of such a region, in order to show what and how great they are.

In the first volume of the Michigan Geological Reports, Major Brooks gives the results of his examination of these older rocks in the Lake Superior region, and plainly says that he considers his work as merely a fair beginning of a great task yet to be finished.

On me now devolved the continuance of the Survey, and the Report now presented to you embodies the results of my work during three summer seasons in the Marquette district, and of one season in the Menominee district.

The perusal of the Report will show what has been accomplished, and how far our knowledge of this large and interesting country has been extended; and I will now specially designate what remains to be done, and the reasons for its immediate execution.

The structure of the Upper Peninsula is so complicated, its extent so large, and the greater portion so difficult of access, that considering these facts I believe I have accomplished during the time aboved stated as much as could be done well; nevertheless, I am more than ever convinced that years of research are necessary to complete these geological examinations as far as possible, and that even then many points concerning the history of the formation of the earth's crust will remain an unsolved problem, because

nature has in part destroyed her own vestiges by building up new structures from their material.

As regards the necessity for an immediate continuance of the Survey, I desire to call the attention of your honorable Board to the fact that a geological examination of a district like the one under consideration cannot be made with expediency, accuracy and a due economy, unless advantage is taken of the work done by the private explorations, which afford the geologist valuable information not otherwise to be had without a great expenditure of time and money.

The State Geologist thankfully acknowledges that much of his Report is based upon information derived from the borings and test-pits of private explorers, and he hopes that he is in some degree able to repay them by such suggestions as he can offer concerning where to explore and where an examination will entail only a pecuniary loss. He believes that during the past year he was able to give advice which saved many times the cost of the annual survey, and that the best encouragement for the development of the mineral resources of our State is by averting fruitless expenditures in futile explorations.

The most favorable time for continuing the survey of this district is, then, while the test-pits remain open, for in a short time the caving-in or filling with water will deprive the geologist of such information as they now afford. Moreover, while these private explorations are going on it is well if the State Geologist can be at hand to give impartial advice based upon scientific principles.

Very respectfully yours,

C. ROMINGER,

State Geologist.

INTRODUCTION.

DURING the progress of the Geological Survey of Michigan, instituted by the Legislative Assembly of 1869, Messrs. T. B. Brooks and Raphael Pumpelly were intrusted with the investigation of the geological structure of the Lake Superior district.

The results of their labors, continued during three successive summer seasons, have been published by the State authorities in 1873, in connection with my own report on the eastern portion of the Upper Peninsula, in two volumes, accompanied with an atlas of maps and sections.

The interesting and valuable documents by these two gentlemen have added a great deal of information to our knowledge of the structure of that country which we received from the previous reports of a number of able scientific observers, such as Douglas Houghton, Jackson, Foster, Whitney, Whittlesey, Credner, and others; but even now, if we should ask the authors of these latest Reports whether they consider their work done, and to have given a full, satisfactory description of the geology of the country, I have no doubt they would answer in the negative; they would say, Our work is a mere beginning; the time bestowed by us on the investigation of so large an area and of so complicated a structure was totally inadequate to the task, which for years to come will engage diligent observers to accomplish it, and this only partially, never completely, as the different phases of the progressive development of the earth's crust have not all left traces behind them sufficiently distinct to construe from the observable parts a connected history of the events of creation. Creation consists in a constant change of things; it continually works over the same material, destroying in one place and building up in another, in a

modified form and combination. We can therefore never expect to see the vestiges of all the successive transformations which took place during the lapse of ages completely preserved, because the same material was always utilized for new purposes. If we commence to trace from our present time backward the different changes in the surface of the globe, we find for the periods next preceding our days abundant facts by which we are enabled to form an approximative idea of the topography of the earth at these times; we can understand by their anology with present organisms the full organization of extinct forms of animals or plants, of which only imperfect fragments are found inclosed within the sedimentary rock-beds. But the farther we step back in tracing the history, the more we feel the scarcity of facts to prove our suggestive ideas; and finally, we are altogether left in the dark, and have to resort to hypothetical speculations, or acknowledge in modesty to have arrived at the limits accessible for the human conception. In the present instance we are not under the necessity to go so far back; still we have to examine very old rock-formations—rocks supposed to be the earliest sedimentary deposits. The study of more recent sedimentary rocks is comparatively much easier, as we find them in an undisturbed succession piled one upon another; and most frequently each group of sediments, representing a certain period, incloses also a certain class of animal or vegetable remains peculiar to this horizon, by which contemporaneous formations can be identified with certainty, even if the lithological characters of the rock-beds should be widely differing. The rocks we have to examine are totally devoid of such organic remains; whether none existed at that time, or whether the conditions for the preservation of such remains were not favorable, is a question about which scientists disagree. In determining the relative age of these rocks, we have nothing to go by but their lithological characters and their order of succession. The first are very changeable, if we compare distant localities, and can be little relied upon; the other criterion of the age, seemingly infallible, loses much of its importance by the great dislocating disturbances to which these older rocks were once exposed: they have lost their original horizontality, and hold all sorts of inclined, erect, or overtilted positions, making it often impossible to decide which is the upper or lower side in

the succession. Moreover, we find these sedimentary beds often considerably altered, resembling, externally and in chemical composition, the crystalline rocks of truly volcanic origin, which likewise form a large proportion of the surface of this region, and which have by intrusion commingled with the altered sedimentary rocks in the most varied manner.

The difficulties in the study of these ancient rocks, indicated by the previous remarks and the incompleteness of our present information about them, were fully comprehended by the members of the Board of the Geological Survey; they decided therefore to continue the commenced investigations, not alone in appreciation of the economical importance of a thorough knowledge of the geology of this part of the State, which by its mineral wealth belongs to the most favored spots on the continent, but they thought also the pride and duty of the citizens of this commonwealth required it to contribute to the promotion of science in general, with the same liberality as many other States have done and are still doing, and to have so interesting a part of its territory fully examined.

In consequence of this decision the Board directed me to lay before them the plan I intended to follow in making the explorations. My suggestions were to examine with careful accuracy certain small circumscribed districts, so selected as to embrace the most important rock-formations developed in the region, thinking such a course would lead the quickest to a correct recognition of the structural arrangement of the earth's crust, not only there, but over the whole territory where similar rocks compose the surface. This plan met their approval.

Indispensable for the successful execution of this plan is an accurate topographical map on a large scale. The Government maps of the linear survey of the United States, projected on the scale of two inches to the mile, would answer the purpose admirably; but it is to be regretted that so little attention was paid to the topographical details of the country in their construction, partly by total omission, partly by false representation. The points intersected by the network of measured lines, dividing the surface in squares of a mile in extent, are usually correctly located, but the course of creeks and rivers through the interior of such squares, and the hills inside of the circumscribed lines, were

merely located by guess-work, which led to considerable errors. Under these circumstances I was compelled to supply the topographical deficiencies of the maps, and to correct their errors, which is a very slow, time-robbing work, requiring an often repeated crossing of every square mile, noting the distances by counting the steps taken in a certain compass direction, in order to locate the drainage channels and surface elevations in the interior of the sections in their proper positions, which is an important requisite of a geological map, as the nature of the rock-formations composing a spot generally determines the form of the contour lines of its surface, by which the geologist may often be enabled to foretell from a distance what rock-formation he likely will find by visiting the spot to be examined.

While performing this topographical work I came across a number of instructive outcrops, which otherwise might have escaped my observation ; and in so far I feel fully compensated for the retardation of the geological work by the topographical. Doing the work in this slow way, I became satisfied that my adopted plan was, after all, the most expedient way to become acquainted with the structure of the country, and to decipher the much-obscured records of the history of this part of the globe, written on the rocky leaves of nature's book. Those familiar with the labors of exploration will not be surprised if I tell them that, straining all my energies, I could not accomplish more in a summer season than to make the examination of about sixty square miles. I selected the environs of Marquette as a starting-point for my explorations, taking in a strip of land about ten miles in width from north to south, and extending the examination of this belt as far westward as to include Lake Michigamee.

Within the indicated space nearly all the older part of the Lake Superior rock-formations is represented ; it includes the majority of all the iron mines worked in the district, and the numerous artificial openings made by the miner greatly facilitate the labors of examination. Another advantage is the location of the H. & O. Railroad along the centre of the examined strip. The manager of the road, Mr. Sam. Schoch, most liberally offered the State Geologist, during his engagement, free travel over it, and I am happy to have here an occasion to express publicly my cordial thanks for these favors tendered to me as an official of the State.

MARQUETTE IRON REGION.

GENERAL TOPOGRAPHY.

DURING the past three summer seasons I have extended my investigations over about 200 square miles, embracing the environs of Marquette, Negaunee, and Ishpeming, or, more accurately indicated, six townships—namely, Town 48, range west 25, 26, 27, and Town 47, range west 25, 26, 27—were carefully examined by me, and a special topographical and geological map constructed of this district, on a scale of two inches to a mile. Besides, I have examined all the important mining locations, not inclosed within the named six townships, as the Washington, Champion, Republic, Spurr, and Michigamee mines.

The surface of this area is extremely broken and hilly. It rises by degrees from the level of Lake Superior to an elevation of about 800 or 900 feet, but reaches in some summit points a height of 1000 or 1100 feet. The outlines of the hills are generally rounded, notwithstanding their frequent composition of greatly disturbed, often vertically erected rock-beds, which is caused by the powerful abrasion of all the sharply projecting inequalities of the surface during the drift period, in evidence of which we find everywhere on the exposed rock-faces the marks of drift scratches, all corners rounded, and the surface smoothed, or even polished almost as bright as a mirror, particularly if the rock masses are very hard and compact, like quartzites. In addition to this grinding down of the prominences, a great proportion of the then existing unevenness of the surface became levelled out by the débris left on the spot, often to such an extent as barely to leave the summits of the rock-ridges unincumbered, and large spaces are by accumulated drift-masses completely covered, and represent extensive plateau lands.

A disposition of the surface elevations in parallel ranges trending from east to west is plainly obvious, and is in causal connection with the upheavals of the rock-beds in this principal axal direction of the disturbing forces; still these mountain ridges are rarely continuous for any great length, but usually are found cut up into more or less isolated rounded knobs, clustered together in rows of the indicated direction. The ridges never reach an elevation of more than 200 feet above the surrounding general surface; usually they are lower, from 50 to 100 feet in height, and frequently we find low rounded rock-knobs not over 10 feet high, scattered over drift-covered plains. The shore near Marquette is partly bordered by rock cliffs 20 or 30 feet high, which, some distance back, gradually rise into rock-spurs 150 or 200 feet above the water-level; but the largest portion of the shore is formed by drift bluffs forming distinct terraces, of which the lower one is about 25 or 30 feet above the water-mark; a higher one is found on an elevation of 80 or 85 feet. North of Marquette harbor, between the Lighthouse Point and Presque Isle, low sand plains and partly marsh lands surrounding the outlet of Dead River form the shore belt; a half mile or more further inland the drift terraces rise, or the rocks come to the surface, first in isolated smaller knobs, then in larger connected mountain masses. The terraces near the lake shore are not the only ones in existence; the drift plateaus on higher levels more remote from the shore are clearly rising in terrace form one above the other, and the well-stratified alternating beds of sand, gravel, and clay composing them evince the former stand of the water to have been 800 and 900 feet above the present level of Lake Superior.

I recall the attention of the reader to a statement made by me in the last Report on the Lower Peninsula, where I mentioned the deposition of well-stratified sand and gravel beds at an elevation of 1100 feet above the level of Lake Huron.

The undulating summit part of the highlands west of Marquette locally expands into marshy plains, from which numerous creeks take their source, or the surface declines more rapidly into kettle-shaped depressions, filled by splendid bodies of crystal clear water. More than thirty lakes, from the size of a few acres to over a square mile in extent, can be counted on the examined district.

Sometimes three or four of them are found in close proximity, one from 5 to 30 feet above the next one, and all connected by creek channels, or more abruptly by rapids and cascades.

The numerous creeks and outlets of the various lakes collect in three principal drainage channels—in the Dead River, the Carp River, and in the Escanaba River. The first two have an eastern and quite tortuous course, flowing sometimes sluggishly through meadow lands; but for the most part they make a rapid descent, and each of them has several beautiful cascades to leap before it reaches Lake Superior. Dead River enters it two miles north of Marquette; Carp River two miles south of the town; Escanaba River flows southward into Lake Michigan. The head branches of the three rivers approach each other very closely, and two of such opposite streams frequently are fed by the same marsh lands.

The district was once heavily timbered, partly by hard wood, partly by pine; the marshy portions are occupied by almost impenetrable cedar thickets; not so often by tamarack, by alder-bushes, or other lacustrine trees and shrubbery. Since the settlement of the country the forests have been pretty well cleared off in the vicinity of the mines and furnaces; large parcels of timber land have also accidentally suffered destruction by fires and wind storms, but very little of the cleared lands has been cultivated and tilled, as agricultural pursuits have so far not been considered equally well remunerating as the working of mines. Many of the clearings have therefore already recovered their forest nature by a vigorous new crop of seedlings of poplar, maple, and other trees of rapid growth. Other places once covered by fine forest trees growing on a thin crust of soil with a rocky underground, after being accidentally destroyed by fires and wind storms, could never recover; the little crust of soil became speedily washed off by the rains, and the naked usually drift-polished rock faces can often be noticed for miles in length on the crests of ridges still bearing here and there the blackened stump of a gigantic pine-tree, the growth of former times, whose wide-spreading roots entered every available fissure.

GENERAL REMARKS ON THE GEOLOGY OF THE DISTRICT.

With exception of the previously mentioned drift masses, which cover a large portion of the surface, and some isolated patches of Silurian sandstones resting horizontally on other rock-formations, all the remainder of the surface is formed either of crystalline masses of granite, syenite, diorite, and kindred rocks, or else by stratified sedimentary beds, many of which are found in an altered semi-crystalline condition, and all in a highly dislocated position, lifted up into all sorts of inclination, from the horizontal to the vertical, or even completely overturned; they are frequently found shattered into fragments, which often are subsequently recemented into a breccia, or we find them curved and coiled or corrugated in a high degree, which proves them to have been in a plastic condition at the time of their upheaval. The upheaving forces evidently acted in a certain constant direction, which coincided almost with east and west; accordingly we observe the previously mentioned parallelism of the rock-ridges in east and west rows, and with a dip to the south or to the north. Local deviations from this rule are not uncommon, but this does not interfere with the correctness of the general observation of regional geology.

Examining the order of distribution of the different kinds of rock, we find the crystalline granitic masses principally confined to the northern and southern limits of the examined territory, while the stratified and metamorphic beds occupy its central portion. The dip of the strata on the south part is almost invariably directed to the north, and on the north side to the south, with exception of the environs of Marquette, where the stratified beds have a decidedly northern dip, which probably indicates their being in an overtilted position. According to this we may with propriety consider the examined area as a synclinal trough of granite, which by the upheaval of its northern and southern margins caused the inclosure of the incumbent sedimentary strata between its walls and their simultaneous uplift and corrugation into parallel folds by the lateral pressure exerted from its rising and approaching edges.

We find these upheaved granitic and sedimentary rock-masses intersected in irregular transversal directions by narrower rock-belts of a compact more or less crystalline structure, which evidently represent lava streams subsequently intruded from beneath, which intrusion seems to have occurred at different periods, as we observed one kind of these rock-belts intersecting the other, and both kinds to differ in chemical composition and external aspect.

SPECIAL CONSIDERATION OF THE GEOLOGICAL STRUCTURE OF THE DISTRICT.

The granitic rocks of the Marquette district are, in the Report of Major Brooks, identified with the Laurentian series of the Canadian geologists, and the incumbent sedimentary and metamorphic rocks with their Huronian series. By comparing the descriptions of the Laurentian formation, as developed in Canada, with the granitic exposures observable in Michigan, or specially in the Marquette district, I can not see so strong an analogy between them as to identify them without hesitation; while I indorse the identification of the other group of rocks with the Huronian, although they differ too in some degree.

The Laurentian rocks are represented as a succession of altered sedimentary rocks of crystalline but tolerably well-preserved laminated structure, principally of gneissoid, partly of granitic character, with interlaminated large belts of limestone, of quartzite, of conglomerates, stratified belts of iron-ore, graphitic layers, and of serpentine, besides a large variety of other accessory minerals dispersed through the various beds.

In the Marquette district gneissoid rocks have a very limited occurrence, while granites of a massive non-stratified character largely prevail. Limestone belts, so characteristic of the Laurentian in Canada, have never been noticed in alternation with granitic rocks in Michigan; likewise quartzite belts and stratified layers of iron-ore are unknown in such a position, if we except the smaller irregular transverse quartz seams intersecting the granitic rocks and concretionary masses of iron-ore accumulated in fissures and pockets; finally, of the great variety of accessory minerals

abounding in the Laurentian rocks, the granites of Marquette are almost if not altogether destitute.

Great stress is also laid on the discordance existing between Laurentian and Huronian rocks ; and Major Brooks mentions a few localities where he observed a discordance between supposed Laurentian and Huronian beds, but in no instance did he see the layers in immediate contact ; and even if he did, a discordance between rock-beds which have been subject to such great disturbances, as the older rock-beds of the Marquette region, does not prove anything either way. Conformable beds may be thrown by them into a discordant position, and on the other hand a stratum originally deposited in discordance on the surface of another, may as likely by the act of disturbance be pushed into a perfectly conform position with it. As far as my own observations go, I have never been able to discover any positive proof of an existing discordance between the granites of Marquette and the adjoining Huronian beds ; on the contrary, outcrops of the two kinds of rock supposed to represent the contact of the two formations exhibit everywhere a remarkable parallelism in strike and dip, and in a good many localities, where belts of granite are found interlaminated between the Huronian schists, the conformity is perfect ; but I am far from believing that these conformably interstratified bands of granite ever had been formed there as regular members of the sedimentary series ; I consider them as intrusive masses, as I will prove in some of the subsequent pages. To shorten this discussion, I declare at once my serious doubts whether the granites of the Marquette region represent the Laurentian series of Eastern Canada, which I never had an opportunity to study in the field, but which is represented to be a much older formation, pre-existing as a surface-rock before the Huronian sediments began to form, while according to my own observations the granites of Marquette are eruptive masses which came to the surface after the Huronian beds were already formed, and by their eruption caused not only the great dislocations of the Huronian formation, but the half-molten plastic granite masses induced by their contact with the Huronian rock-beds, also their alteration into a more or less perfect crystalline condition, and commingled with them so as to make it an embarrassing task to find a line of demarcation between the intrusive and the intruded rock-masses. The syenitic

and gneissoid hornblende rocks connected with the granites differ so little from the crystalline hornblende rocks of the Huronian series, that I look at them merely as differently advanced stages in the transformation of the same material : those nearest to the focus of altering influences are more completely transformed and restored to the domain of the volcanic nucleus ; the more remote strata were less changed, and retained distinct marks of their sedimentary origin ; but if this view is correct, it cannot be expected to find traces preserved of the conformable or non-conformable deposition of the Huronian layers on their substratum. In giving a description of the Huronian rock series, Major Brooks originally divided it in nineteen different groups, to which he subsequently added a twentieth. I cannot agree to accept this method for my own descriptions ; the subdivisions made are altogether too numerous, and also otherwise seriously objectionable. Beginning below with his groups from 1 to 5, he never made an attempt to define them ; we are occasionally informed, by reading the book, that such and such an outcrop represents Group 1, 2, or any of his subdivisions, and this is all. As Groups 7, 9, and 11, certain dioritic outcrops are designated, and considered to be regularly interstratified layers in the sedimentary succession, while I have full reasons to consider them as intrusive masses, belonging to a lower horizon of the Huronian series, which by volcanic pressure have been forced through or between the incumbent rock-beds, wherever a chance for it was offered, and consequently are found one time in contiguity with this, another time with another stratum, as it happened to be the surface-rock of the spot.

Groups 8, 10, 12, 13, and 14, being the ore-bearing rock-beds, are more carefully described, as the special object of Major Brooks' Report was principally the exhibition of the economically important members of the Lake Superior series of rocks.

Groups 15 to 20, intended to comprise a series of younger beds developed in the western part of the Marquette region, are unnecessarily multiplied into vaguely defined subdivisions. Subsequently Major Brooks identified strata of the Menomenee River district as representatives of Groups 15 to 20, which lithologically have no similarity with those of the Marquette district, adding still more to the confusion already existing. Describing the Huronian

series, I propose to make the following subdivisions in an ascending order :

I. Granitic group.
II. Dioritic group.
III. Quartzite group.
IV. Iron group.
V. Arenaceous Slate group.
VI. Mica schist group.

In a seventh chapter I have described the serpentine formation, in an eighth the vulcanic dyke-masses, and in a ninth the fissure veins.

The Quartzite group should, according to my present information and views on the structure of this region, be placed as Group IV., while the Iron group as the older formation should be ranged in as Group III. ; but I have not altered the originally adopted arrangement, as in the vicinity of Marquette, which will be first described, the Iron formation is not well represented, and the quartzite rests directly on the dioritic rock-series, and as an acquaintance with the quartzite formation previous to the examination of the iron formation is a help to the proper understanding of the facts concerning the latter.

CHAPTER I.

GRANITIC GROUP.

I HAVE previously stated that the northern and southern limits of the district are composed of granitic rocks. Granites are also found interstratified with the Huronian schists, right within the city limits of Marquette, and in other centrally situated localities ; but to find the first outcrops of a larger body of granite, forming a continuous belt trending westward, we have to go a mile or over north of the town, to the mouth of Dead River. We find also some islands, called Gull Islands, three quarters of a mile east of the promontory of Presque Isle, composed of granite ; they project only about 15 feet above the water-level, are perfectly denuded of soil and vegetation, and offer a fine opportunity to see various modifications of the granite ; besides, we observe its intersection by numerous dykes of a distinct character. One sort of dyke intersects the other, and is consequently of later date ; they will be specially considered in a subsequent chapter. Presque Isle, an isolated mountain mass comprising one half a square mile, and of about 150 feet elevation, is, contrary to our expectation, composed of an entirely different rock-mass, principally of magnesian composition, partly silicates, partly carbonates. It is to all appearances an igneous outburst, greatly corrugated and shattered, pervaded by a dense network of sparry seams, and by asbestine bands with transverse fibres. A great proportion of the superficial masses is in a state of rapid disintegration, friable into a crummy sand-mass. This eruptive rock is capped with Silurian sandstones, the lower ledges of which are a coarse conglomerate, principally made up by rounded pebbles of the underlying rock. The sandstones are not entirely horizontal, but this is not a dislocation by upheaval, and can with propriety be at-

tributed to an often observed adaptation of sedimentary layers to the undose inequalities of the subjacent surface. A belt of marsh lands surrounds the promontory from the land side, but at no great distance all around it are small granite knobs rising above the sandy plains, and the bay north-west of it is crowded with granitic islands ; the largest of the islands is called Middle Island, or also sometimes Partridge Island ; it has an elevation of about 80 or 100 feet, and is well timbered, but all its circumference is formed by bold cliffs of granite in alternation with belts of gneissoid rocks, and pervaded by many dykes of a dioritic and partly of a doleritic character. On its south side we find also a patch of Silurian sandstones resting on the granite. West from here is a very broken, hilly country, all underlaid by granite. The Dead River winds its tortuous course for a number of miles over ledges of granite. Near its mouth the rock projects only in solitary knobs from 20 to 60 feet in height above the sand-covered lowlands ; a mile west of the shore the ground begins to rise more rapidly, particularly on the north side of the river and south of Campo Creek, which runs parallel with the lower course of Dead River. The interval between the two water-courses is occupied by a granitic mountain body of extremely rugged character ; its summit part is divided into great numbers of rounded knobs and shorter ridges forming parallel rows, with an abundance of rock exposures. The height of the ridge at its eastern termination, near the Marquette powder-mill, is 150 to 200 feet, but rapidly increases westward to an average elevation of about 400 feet. The north slope of the ridge, toward Campo Creek, is little incumbered by drift masses, and offers one of the best opportunities to study the granite of this region, together with its interstratified dioritic belts and the numerous dykes intersecting it transversally. Toward the south the slope is less abrupt ; the rocky summits seen from this direction repose on a broad rolling drift plateau, which terminates toward the Dead River with steep bluffs.

On the north side of Campo Creek a part of the valley is lined with vertical bluffs of granite, but down toward the lake the valley has a rounded drift-covered slope, which on its height expands into a spacious rolling plateau which extends to the lake shore ; but its edge all along the shore northward is lined with granitic rock-bluffs. A mile north of Campo Creek this plateau is crowned with

several high peaks of granite. Sugar Loaf Mountain, the largest of these peaks, is not far from the shore, and touches it with its rapidly descending eastern slope.

A mile west of the Sugar Loaf is an equally high granite mountain, called Mount Crispy, on which the Lake Survey has erected one of their stations. It is separated by a deep depression from the Sugar Loaf, which toward the south forms the valley of a tributary of Campo Creek, northward it declines into the valley of another creek flowing through a good-sized lake, before it enters Lake Superior, in the bay on the west side of Granite Point, an isolated knob of granite in a soft disintegrating condition, situated at the end of a narrow land-tongue covered with sand and underlaid by Silurian sand-rock, which latter forms the greatest part of the shore line as far south as the foot of Sugar Loaf Mountain, where granitic cliffs begin.

I observe this large granitic body to be much less intersected by dioritic rock-belts, than I found it in the granitic range between Campo Creek and Dead River, where several subordinate dioritic ridges of considerable extent are wedged in between the crests of granite.

On the south side of Dead River the granites are, for several miles westward from the mouth, not often seen at the surface ; the valley, after leaving the marsh-land with its few low knobs of granite, is generally formed of slowly ascending, rounded, drift-covered hill-slopes, although the river bed is nearly all the while formed of granite ledges in connection with schistose belts of chloritic or dioritic character, which in the more northern exposures are not seen associated with the granite. Farther up stream, near Collinsville and the Bancroft furnace locations, the valley becomes narrower and the drift hills increase in height, frequently allowing the granite to come to the surface on their slopes, and crowned with insular granitic prominences of more circumscribed or of a larger extent. The granite outcrops south of Bancroft's furnace alternate with belts of peculiar hornblendic or dioritic rocks, parallel with the trend of the formation, and are transversally intersected by quite numerous seams of dioritic and of doleritic nature. A conspicuous landmark is formed by a cluster of granite knobs at the section corners between 7, 8, 17, and 18, of T. 48, R. 25. The surrounding country is all a drift-

covered, undulating plateau, which westward falls off in abrupt bluffs toward the Dead River valley above the former location of Stone's mill.

The river flows here in curious curvatures through a broad swamp valley, passing repeatedly almost the same spots. At the mill site it breaks through a granitic barrier and through chloritic schists and diorites, conformably interlaminated with the granite belts, and falls in numerous rapids and stair-like offsets within half a mile more than 100 feet, escaping the Narrows at Bancroft's furnace, near its union with a large creek, flowing likewise over granite ledges in hurried descent from a western direction. Entering the valley of this creek, we see it on the north side bordered by high steep drift-hills, which form on top an extensive plateau, spreading in a width of over half a mile in a north-westerly direction beyond the limits of the examined district. The nucleus of these highlands is granite, which occasionally shows itself along the margins of the plains in bluffs. The south side of the valley is superficially formed by drift, and the underlying granite is only seen in the ravines.

At the first bifurcation of the creek the granite divides into a northern and southern belt, and between these, chloritic schists and dioritic rocks occupy an area of from two to three miles in width, which extends for many miles westward ; but in the western portion of this belt, which is of a very broken hilly character, a large proportion of the dioritic rocks and schists is overlaid by slaty and arenaceous beds of a younger period of the Huronian area. The northern borders of the schistose belt approximately coincide with the north line of the Town. 48, R. 26. The southern belt of granite follows the course of Dead River on its north side, and is seen in a last outcrop in the S.E. quarter of the S.W. quarter of Sect. 10, Town. 48, R. 26. On the south side of the river the granite exposures extend much farther westward to the west end of the township, and beyond following the south line of Sects. 15, 16, 17, and 18 in a quite prominent knobby ridge ; it makes its last appearance near the centre of Sect. 13 in the next township, R. 27 ; further on, diorites and schists continue the hill-range, and soon also these begin to disappear beneath younger Huronian rock-beds, which almost exclusively cover the north half of Town. 48, R. 27, with exception of the north-east corner, where

near the location of the Holyoke mine the older schistose and dioritic rocks occupy the ground. A more isolated body of granite, which, however, evidently forms a continuation of the before-mentioned granite range following the north side of Dead River, projects at the edge of a large drift-covered high plateau in large vertical walls following the south line of Sect. 6, Town. 48, R. 26. Associated with the granites of this locality are chloritic schists and diorites. On the northern edge of this plateau the interlamination of granite seams between the schists is seen in several exposures. Belts of granitic nature are also found interstratified with the dioritic schistose group in the south part of Sects. 1 and 2, Town. 48, R. 26. This rock is generally very compact, fine-grained, and consists principally of feldspar, with small proportions of quartz ; locally the rocks become porphyritic by the secretion of large but indistinctly defined feldspar crystals within the granular, almost aphanitic, ground-mass ; likewise is their transition to gneissoid structure frequently observed by the segregation of delicate micaceous or chloritic laminar streaks in the mass. Besides these granitic belts the schists inclose also large belts of a coarse conglomerate rock in the last-mentioned locality, consisting almost exclusively of bright red granite pebbles of all sizes, with exquisitely well crystallized grain, quite different from the associated granite seams, and of fragments of chloritic schist ; all cemented together by the same chloritic schistose material as the inclosed fragments, but usually an amorphous flinty coating intervenes between the pebbles and their schistose cement.

Turning our attention to the granites which form the south margin of the synclinal basin of the Marquette district, we notice a striking difference in their relations to the surface of the country. While the northern granite outcrops occupy, always or nearly so, the highest elevations, and constitute the most conspicuous ridges, we find the granites on the south rim of the basin always occupying a lower level than the younger Huronian rocks. The granites form the floor of the immense pine plains expanding on the east side of the Escanaba River, and low rounded bubble-like prominences scattered over the sand-covered level are the only places where the rock is found exposed ; north of the plains we see the quartzite hills of the Goose Lake district rise abruptly to the height of 300 feet above them. On the west side of the Es-

canaba River, along its west branch, the granitic area is considerably more mountainous, broken up into innumerable knobs with sharper contours, presenting precipitous rock-walls; the summits of these are on a level 200 feet lower than the row of steep hills adjoining them on their north side, and composed of the younger Huronian rock-beds. This granite belt disappears farther south beneath the Silurian deposits, but in a number of localities the iron-bearing Huronian beds also have been discovered to overlie it in the south. The Smith mine is opened in one of these deposits, and several other promising localities have been more recently discovered in this southern granite district.

The topographical limits of this southern granite belt toward the synclinal basin may be described as follows: Granitic seams are noticeable within the dioritic schists exposed on the shore of Lake Superior, near Harvey's furnace, but the first good outcrops can be observed near the quarter-post on the west line of Sect. 1, Town. 47, R. 25. From here it passes through the south part of Sects. 2 and 3, thence, curving southward, intersects Sects. 10, 9, 8, 17, and 18, of the same township, crosses diagonally Sect. 24 of the next western township, follows the north line of Sect. 26, and thence continues in almost due west direction through the Sects. 34, 33, and 32, from here, curving more northward into Sect. 30, it enters the south part of Sect. 25 of Town. 47, R. 27, and trends in straight western direction across the whole township, and is found to occupy again almost the entire Sect. 25 of Town. 47, R. 28. Farther west my explorations did not extend in this southern part of the district. Isolated protrusions of granitic rock-masses are in various places found north of the described rim; one of these can be observed in the S.W. quarter of the S.E. quarter of Sect. 19, Town. 47, R. 27, overlaid by the iron-bearing beds of the Saginaw mine.

The two granite belts on the north and south side of the synclinal basin differ very little in structural composition; but in different localities the lithological character of the rocks changes considerably by differences in grain, colors, and relative proportions of the component minerals in the granitic and hornblendic rock species.

The granites of the Marquette district are usually middling coarse-grained, of reddish tints, oftener composed of a magma of

incompletely defined crystals imbedded within a granular interstitial mass, than of well-formed completely defined crystals; its fracture is therefore rather generally of a dull lustre. Red orthoclas, of a milky appearance, in lighter or darker shades of color, is the prevailing constituent, and large bodies of granite are composed of orthoclas mingled with variable proportions of glassy quartz-grains, without mica or any other mineral substituting its place. The micaceous constituent of these granites, where it does enter into the composition, is rarely well crystallized in brightly shining larger leaves, although it occurs occasionally, but usually has a minutely scaly form and a dark green color approaching to chlorite by gradations, or is replaced by hydromicaceous fibroso-granular substance, generally called talcose, from its soft, greasy feel and its lighter color, with partial transparency in thin seams. This latter mineral imparts to the granite an irregular sub-schistose cleavage, causing it to disintegrate more readily than other kinds into wedge-like shelly fragments. Such granites are seen in outcrops near the Marquette powder-mills, associated with schists of chloritic nature; but they occur almost regularly on the south side of the synclinal basin on the line of contact between the normal granites and the lower quartzite formation, and seem to be the product of metamorphosis of the quartzite, as we find all degrees of transition, from the ordinary quartzite into a regular granitic rock-mass. The least altered beds of the quartzite are seen pervaded by pale yellowish green streaky seams of hydromica, whose proportion of intermixture increases with the progress of alteration. At a more advanced state we find flesh-red feldspar crystals sparingly segregated within the mass, which finally so increase in number as to give the rock the character of a granite or protogine. Examples of such a transition can be observed near the quarter-post on the east line of Sect. 2, Town. 47, R. 25, where a natural section through a quartzite knob exposes the bubble-shaped arched elevation of the ledges, in the centre of which the granite just shows itself at the base in the described modifications of metamorphism, and at a short distance from the place ordinary granites appear in the outcrops. Similar granite-like altered quartzites, beautifully red and white speckled, form large perpendicular bluffs in the south half of the N.E. quarter of Sect. 30, Town. 47, R. 26. Another good exposure of such

metamorphosed rocks can be observed on the north side of the lake in Sect. 9, Town. 47, R. 25. Some of the granites have a laminated gneissoid appearance, from the distribution of the micaceous or chloritic constituents of the mass in parallel linear interrupted streaks, but it is doubtful whether this is an indication of a former sedimentary lamination. I have in several instances seen narrow intrusive granitic dyke-masses similarly laminated by the parallel arrangement of the mica scales in them.

Nearly all the granites I observed were mingled with more or less iron pyrites, in dispersed small cubical crystals; also epidote not rarely occurs intimately mingled with the granitic crystal magma, but more frequently it is found to fill the smaller fissures in the rock as a solid cement mass. Other minerals are altogether uncommon, if ever found as accessories of the granite. On the Huron Islands, 60 miles north of Marquette, the granites, apparently identical with those around Marquette, contain occasionally delicate thin leaf-like sheets of metallic copper seemingly embodied with the mass, but on close inspection they are found to cover the surface of hair-fine fissures in the rock, which suggests to me a secondary deposition of the copper into the fissures by galvanic action. Almost constantly associated with granitic outcrops, we find large belts of gneissoid, well-laminated rocks, consisting of a brightly shining blackish or dark green hornblende in flattened scaly crystals in laminated alternation with similar linear seams of granular feldspar and quartz intermingled; not rarely also black mica enters into the composition of the rock, or it takes altogether the place of the hornblende and constitutes a genuine gneiss.

The rock is usually compact, not very fissile in the direction of the laminar striation; if the hornblende in its composition preponderates over the quartz and feldspar, which is often the case, it has a uniformly greenish black or bluish black color, with bright lustre of the crystal facets. More feldspar in the composition gives the rock a delicately white and black striped appearance, which becomes particularly obvious on weather-worn surfaces of cross-sections.

This stratified banded rock, in contiguity with the granite and alternating with it in parallel belts, often becomes completely intermingled and entangled with it. The granitic masses intersect the gneissoid, enter wedge-like between them in the direction of

the lamination or transversally, inclosing strips of the gneissoid ledges between the loops of the anastomosing granite seams, and moreover, frequently the so-intermingled masses are curved into the most curious coils and serpentine flexions, which evinces their almost liquefied plastic condition at the time their intermixture took place. A splendid exhibition of these rocks, intermingled in this most singular mode, whose gayety of colors is yet augmented by additional seams of light green epidote, can be seen on the large denuded rock-walls forming the north-west shore of Middle Island, a sight not only interesting for the geologist, but attractive for every one who happens to pass by. Other similar exposures can be seen in the centre of S.W. quarter of Sect. 6, Town. 48, R. 25, but the denudation is not near so complete as in the first-mentioned locality. The southern granite belt is associated with similar gneissoid hornblende rocks as the northern, but frequently we see here the hornblende partially or completely replaced by black mica, which micaceous nature of the rock is in the northern belt less common. South of the Republic mines, gneissoid rocks have a large display, but I have only superficially passed over that district.

In association with the granites, a second form of hornblende rocks is observed, which, unlike the former well-stratified beds, forms crystalline non-stratified masses resembling eruptive dykes. These rocks never cover areas of as large an extent as the gneissoid rocks, but are more sporadically interspersed narrower belts, although some of them are seen in outcrops of considerable bulk. Picnic Islands, a group of low, naked rock protrusions in the bay, half a mile north of Marquette Lighthouse Point, are composed of this kind of rock. Another large dyke of it, 70 feet wide, intersects the granite of Middle Island, and is well exposed on the north-west shore in close proximity to the above-mentioned rock-walls, exhibiting the contorted intermixture of the granite with the gneissoid rock-belt. Seams of granite run across the hornblendic rock, and again the hornblende rock cuts through the granite masses, so that one hesitates which of the two to consider as the intruded and which as the intruder. The priority in age of one over the other can at all events not be very great. The hornblende rock of the Picnic Islands incloses fragments of the Huronian schists exposed in the vicinity, and also the granite seams on

the island embrace similar schistose fragments; their eruption must, according to this, have occurred subsequent to the deposition of the schists. On Middle Island again we find a large doleritic dyke to intersect both the hornblende rock and the granite, which proves, on the other hand, the priority of the latter over the doleritic lava stream.

The rock is a mixture of rather large blackish green hornblende crystals, with variable proportions of reddish orthoclas, besides a white granular interstitial mass of anorthic feldspar, which often seems to be only present with exclusion of the orthoclas, but the hornblende always preponderates considerably over the feldspathic components; the color of the rock is therefore usually uniformly dark green on fresh fractures, but becomes spotted with white by long exposure to atmospheric influences. By greater abundance of the feldspar, the red and whitish crystals of the feldspar are also visible on freshly fractured surfaces, and the rock is speckled throughout. Black mica is an ordinary accessory component, besides small granular crystals of iron pyrites. Epidote is also found disseminated through the mass, and occurs in great abundance as filling material of fissures in the rock, associated with calkspar, which occasionally contains nodules of copper pyrites. Some of the fissures are replenished by flesh-red feldspar.

The Picnic Islands are, besides the belts of ordinary granitic rock which traverse them, intersected by narrow dykes from three to five feet in width, which consist of a compact minutely granular feldspathic ground mass of dusky reddish gray color, and with an almost flinty fracture. Within this mass are small scales of black mica copiously segregated, and arranged in linear interrupted subparallel seams, which impart to the rock a laminated gneissoid appearance. The lamination is vertical, parallel with the walls of the dyke. We see here a fine example of gneissoid structure developed in a lava mass, and totally independent from a sedimentary arrangement of the material; the laminated structure of the gneisses is therefore not necessarily a proof of their former sedimentary origin.

On the sandy flats of the mainland adjoining the Picnic Islands, several masses of largely crystalline hornblende rocks are found in the outcrops in intimate connection with dioritic schists; they contain a large amount of iron pyrites, and the hornblende crystals are more fibrous, with less lustre, than the rock on the islands, and seem to be destitute of feldspar. West of these outcrops, in the S.E. quarter of Sect. 14, Town. 48, R. 25, on the height of a drift terrace, a belt of granite 75 feet wide comes to the surface, adjoined on both sides by well-stratified dioritic schists, which are partly transformed into well-crystallized coarse-grained diorites, or, at all events, the schists are interlaminated with such massive crystalline rocks, and exhibit a transitory gradation from the schistose to the crystalline condition. Many narrower granite belts are observed conformably interlaminated with the schists besides this larger one. The smaller belts are seen in places to wedge out completely, or to divide into side-branches crossing the schists transversally, clearly evincing their intrusive nature. This interlamination of granite seams between the schists can be traced westward for several miles in numerous exposures to a locality in the south-east quarter of Sect. 16, Town. 48, R. 25, where a great number of granite seams of large dimensions is found in alternation with schistose dioritic rocks, and where the true relationship between the two kinds of rock is well exhibited. To omit unnecessary repetition, I propose to describe these outcrops more explicitly in the following chapter, treating of the dioritic group, No. II.

Another class of hornblende rocks, genuine syenites, represent the granitic group in association with ordinary granites in an extensive chain of hills trending westward from the centre of Sect. 23 through the north half of Sects. 22, 21, and 20 of Town. 48, R. 26. They are very showy completely crystalline rocks, in different variations of coarseness in the grain, and of the proportions in the mixture of their constituents, which are a dark blackish hornblende and a reddish gray orthoclas, both minerals in crystals of bright lustre. Quartz is entirely excluded, but the syenites are often associated with belts of the ordinary quartz-bearing granite. Black mica is often an accessory constituent of the syenites, but never in proportions large enough to alter the general hornblendic character of the rock. Iron pyrites is, as in the granites, also in the syenites, frequently disseminated in small grains. This nicely mottled rock, in compact solid masses, would answer for masonry and ornamental monuments better than any other granitic rock in the district, as it takes a fine polish, and is

much more easily dressed than the granite. In some localities of this syenitic range, the rock is of a different character; the feldspar crystals become very large, and form almost the entire mass, while in place of the hornblende, narrow interstitial seams of chloritic schistose nature form the cement for the reddish-colored feldspar; this rock is full of cleavages and easily disintegrates. With the syenites we find rock-belts associated, which correspond with the hornblende rocks of the Picnic Islands; they intersect the others in the form of dykes.

One of such rock-belts is well exposed along the north half of the section line between Sect. 22 and 23, Town. 48, R. 26, which differs from similar belts in the same neighborhood by a considerable increase in the proportion of the feldspathic element, and by the substitution of black mica in place of the hornblende; besides this, the rock contains a large proportion of carbonate of lime, which, being more easily dissolved by exposure to the atmospheric influences, causes it to be very rough and cellulose on the surface in a weathered condition. The feldspar is a greenish-colored anorthic kind.

The hitherto described hornblende rocks, associated with the granites, distinguish themselves from similar rocks occupying a higher position in the series by a much brighter lustre of the hornblende crystals, which in the other mentioned rocks exhibit much less splendor and a somewhat fibrous quality.

Such rocks, of a duller aspect, genuine diorites, composed of a magma of hornblende and feldspar, are frequently found in contact with granite, forming short intermediate parallel ridges, which I consider as eruptive igneous masses; other similar dioritic rocks, found on the boundary lines between the granitic and dioritic subdivisions of the Huronian series, are at the same time in close connection with the schistose beds of the second group, of which they may be more highly metamorphosed portions, but I hesitate to give a positive opinion on their origin. The previously mentioned dioritic ridges occurring in the granite hills south of Campo Creek, in Sect. 4, 5, and 6, of Town. 48, R. 25, I consider as representatives of the eruptive diorite; many of the smaller transverse dyke-masses in the same hill range are identical in lithological character with the larger belts: it is a uniformly dark green rock, the greater part composed of a confused mass of hornblende crystals, imbedded in a sparingly existing granular interstitial mass of feldspar; as accessory minerals we find in it iron pyrites and epidote, besides chlorite. In the outcrops in the N.E. quarter of Sect. 6 the rock is full of cleavage cracks, and readily breaks into sub-rhomboidal fragments; a portion of it is also rapidly disintegrating, and falls into a crummy sand-mass, accumulating at the base of the exposed cliffs as a talus.

Another different kind of eruptive diorite contains a much larger proportion of feldspar in its composition than the former; both minerals, the dark green hornblende and the greenish white feldspar, are in sufficiently large crystals to give the rock a speckled appearance. A cluster of low knobs situated on the south side of Dead River, near the quarter-post between Sects. 10 and 11, Town. 48, R. 25, and other knobs on the north side of the river, in the S.W. quarter of S.W. quarter of Sect. 2, are formed of such diorites and connected granitic outcrops. Similar light-colored speckled diorites occur with the granite in the S.W. quarter of N.E. quarter of Sect. 17, and in the S.W. quarter of the S.W. quarter of Sect. 18 of the same town; in the latter two localities they are also associated with schistose strata. The diorite in the knobs near the quarter-post of Sect. 10, containing a large proportion of reddish orthoclas, in addition to the greenish-white anorthic feldspar, and often also epidote. The smaller clefts in the rock-mass are filled out with brick-red orthoclas or with epidote; larger fissure-veins, principally filled with quartz and calcspar, contain in addition micaceous iron oxide, iron and copper pyrites, epidote, orthoclas; and as a last deposit we find, nearly regularly, the space left vacant by the other minerals filled out by chlorite. Some of these fissures exhibit their walls incrusted by botryoidal chalcedony in alternately bright red and colorless whitish banded layers.

The last described dioritic rocks, in larger bulky masses parallel with the formation, and the narrower transverse dioritic rock-belts to be described in one of the subsequent chapters, are very similar in character of the rock-mass, and have, in my opinion, the same contemporaneous origin by volcanic eruption; they should with propriety therefore have been described together; but as opinions differ on this topic, I gave the description of the larger rock-belts parallel with the granite, in this place, separately.

CHAPTER II.

DIORITIC GROUP.

THE previous description of the granitic group has made us acquainted with so many rocks of nearly equal composition with the diorites, that it appears almost improper to select for this second division the name dioritic group, in order to distinguish it from the first; but as I do not intend to indicate by these subdivisions separate distinct epochs, based on a difference in the rock material, but merely wish to draw artificial lines of demarcation for the convenience of description, the name may be applied in this sense, and is justifiable by the great prevalence of dioritic rocks in the so-named subdivision.

The granites, considered in their present surface position, are, in relation to the stratified sedimentary rocks of the Huronian series, actually the younger rock, so far as the intrusion of very large masses of granite between the stratified sediments can be demonstrated by clearly observable facts, and as the other larger bodies of granite inclosing them from two sides are in direct continuity with the vein granites, and lithologically identical with them. The hypothesis of their contemporaneous eruption is therefore well admissible. But supposing this to have been the case, one may ask, Of what nature, then, was the substratum on which the Huronian sediments were deposited? I answer, Nothing contradicts the possibility of their deposition on a surface of granite already formed; it is even probable to me that it has been so; but if we reflect upon the high degree of plasticity and the almost perfect liquefaction which the concerned rocks subsequently underwent, and upon the dislocating forces, causing the softened and, necessarily by this softening process, considerably altered masses to intermingle almost chaotically, we can no more wonder

that the traces of the originally existing former relative position of the rocks among themselves are greatly obliterated. The records of these periods in the history of the earth's crust, when oceanic sediments commenced to form and fell back again within the grasp of the central fire-focus, as we can observe it in this case, are wiped out, and most likely all our efforts to ascertain the existing original conformity or discordance between such rocks will be in vain.

From such a standpoint, the various crystalline hornblende rocks found in association with the granites could be considered as remelted, completely metamorphosed, Huronian sediments, on account of their nearest proximity to the volcanic focus; while those more remote from it did not altogether lose their sedimentary structure, but still became altered, and frequently streams of the lower melted or emolliated plastic masses broke through them, filling transverse ruptures or entering between the ledges parallel with the bedding.

The rock series comprised under the name of dioritic group is made up by a large succession of schistose beds of a very uniform character, which are interstratified with massive belts of diorite differing in structure from the minutely granular, almost aphanitic condition, to a coarsely crystalline form, and being in chemical composition almost identical with the schistose beds.

The name schists, intended for thinly laminated rocks with an imperfect slaty cleavage, is here used in a wider sense, as many of the concerned rock-beds, although laminated, have very little of a slate-like fissibility. Some of the schists have their cleavage parallel with the lines of stratification, but in the great majority of schists and genuine slate-rocks, their cleavage is in discordance with the original bedding plains, and is the result of an immense pressure acting obliquely on the sedimentary layers, and causing a sliding dislocation of the molecules composing them.

The color of nearly all the rocks composing the dioritic group is dark grayish or blackish green, imparted to them by protoxide of iron, partly, perhaps, intermingled as a mere pigment, but principally as a constituent of hornblende, chlorite and mica, which three minerals, with the addition of feldspar and quartz, are the main constituents of all the rocks of this group. Chlorite frequently replaces the hornblende, and often seems to be a product

of decomposition of the first ; or, in other instances, a green earthy substance results from it, called viridite. A part of the schists belonging to this group, of a minutely scaly structure with a lubricous fatty feel, often called talcose, are not of magnesian composition, and consist to a great extent of an aluminous silicate, named hydro-mica.

The dioritic rock-belts are usually imbedded conformably with the schists, and not rarely an insensible gradation from the schistose condition to the massive dioritic can be observed. In the exposures the massive body of diorite generally forms a nucleus around which, eccentrically, the inclosing rock-masses assume more and more a perfect schistose structure, without an important change in the material, as by close examination with a magnifying-glass the schists are found to be composed of an aggregation of hornblende and feldspar crystals, imbedded within a chloritic or hydro-micaceous or a minutely granular feldspathic ground mass. Other generally narrower diorite belts intersect the schists transversally, which differ little in composition from the conformably interstratified masses, and may, as I previously intimated, represent the lowest, more completely liquefied portions of the rocks in progress of alteration, which were forced through ruptures in the beds to the surface.

The north belt of the granitic synclinal is, on its south side, found in parallel juxtaposition with the schistose dioritic formation, but exposures sufficiently extensive to allow a detailed study of the rocks in their contiguity have not occurred to me. We see the lower part of the bed of Dead River often carved through dioritic schists in contact with granite masses ; but the denudations are too restricted, partly by being under water, partly by drift deposits which cover the rock in the embankments ; but we can so far notice a conformable parallel trend of the formations and the vertical position of the schists adjoining the granite, besides the interposition of narrow granite belts between the schists. An exposure of this kind is seen near the Collinsville furnace ; at the same spot a doleritic dyke crosses the river and intersects all those beds. South of Collinsville a drift-covered hill land rises, which in its ravines has some granitic outcrops. Farther east, at the powder-mill, looking southward, large sandy plains over a mile wide extend before us ; past them, we see drift-covered terraces

forming the foot of an east and west range, commencing at the Lighthouse Point, slowly rising in height to an elevation of about 200 feet, its broad summit dotted with knobby rock-protrusions, consisting of a large succession of well-stratified schists of dioritic or chloritic character, with interspersed massive diorite belts and granite belts, intersected by numerous transverse dykes of various nature. The schists dip under a high angle northward, while in the synclinal arrangement of the strata a southern dip should be expected. The above-mentioned ridge, after its extension for two miles west of the Lighthouse Point, is interrupted by the valley of a creek flowing there in almost a direct northern course along the section line between Sects. 16 and 15, and entering Dead River half a mile south-west of the powder-mills. The valley of this creek presents one of the most interesting cross-sections through the schists of the lower Huronian series. Ascending the valley from its lower end, where the creek flows through drift embankments, we meet, about 400 steps south of the northern section-corners of 15 and 16, with several small knobs of granite almost denuded of soil and washed at the base by the creek. Several narrow belts of a gneissoid rock are seen to intersect the granite in dyke form, they are composed of very bright, somewhat scaly hornblende crystals of a blackish color in intermixture with red orthoclas in laminar, interrupted, streaky seams. The intersection of the granite by an identical gneissoid rock-belt, and the intersection of both by a later dioritic eruptive rock-seam is also seen well exposed on the north side of Dead River, opposite the furnace buildings at Bancroft's. A short distance farther up the creek from the granite knobs, which interval is covered again by drift, the dark green colored, well-laminated dioritic, and to a certain extent chloritic schists, begin to form the embankments in high bluffs, presenting a cross-section through the almost vertically erected beds with a northern dip. While farther ascending the creek, we pass for the distance of half a mile through an uninterrupted succession of such schists, all dipping in the same northern direction. This natural section, representing a succession of rock-beds not less than 3000 feet in the aggregate thickness, may possibly not be the real thickness of the schistose beds, and by plication a repetition of the series may have occurred, but no indication of a folding of the rock-beds is observ-

able. The parallelism and uniformity in the dip of the strata does, however, not preclude the existence of folds causing a repetition of the beds, as continued lateral pressure on a fold of the strata will finally bring the layers of both sides into a parallel contiguous position, while the connecting salient arches of the folds are destroyed by abrasion, and the entering arches are buried in unknown depths and not seen. We could without any difficulty recognize the existence of such folds if the lithological character of different horizons in the series would obviously differ, and a repetition of certain marked beds in an opposite order could be observed; but we find, from one end of the section to the other, a remarkable uniformity in color, structure, and chemical composition of the rocks.

The great bulk of the series is a dark grayish or blackish green, rather hard rock, of delicately laminated schistose structure, but rarely very fissile in this lower geological horizon, or segregated in flaggy layers with even surfaces, and frequently intersected by cleavage seams, causing them to break into rhomboidal fragments. The substance of the schists is a minutely granular mass of feldspar composition, in intimate intermixture with minute crystals of hornblende or partially with chloritic scales, with mica or also with hydro-mica; the distribution of these minerals in the ground mass is laminar, which gives the slabs the delicately lineated appearance on cross-fractures. A gradual, almost imperceptible transition from the schists into massive diorite belts is particularly observable in this lower horizon; the higher schistose strata are often more of an aphanitic texture, and chlorite frequently takes the place of hornblende. Imbedded between the dioritic schists of this section, particularly in the southern portion of it, are very even-bedded light-colored flags cleaving into rhomboidal pieces, which consist of a compact granular feldspathic mass, semi-transparent in their splinters, intimately intermingled with fine scales of white mica and with fibroso-granular linear seams of hydro-mica, particularly well noticeable on the surface of the flags. Within this mass larger crystals of feldspar and of quartz are often segregated, which makes them resemble the porphyritic dyke granites which in the same localities are found interposed between the schists, but the described beds seem to be real members of the sedimentary series. They are observable in the outcrops all

along the range, from the creek to the Lighthouse Point, at which place the light-colored, hard, even-bedded flags, with rhomboidal cleavage, are particularly well exposed on the north side of the lighthouse building. Proceeding in the valley of the examined creek farther southward, we see the dioritic schists exposed in continued succession without an obvious change in their character, but soon we find on the west side, a short distance from the creek bed, high rock-bluffs rising, which are formed of granite, alternating with the dioritic schists in frequent repetition of broader or narrower belts conformable to the schists as they usually appear; but on closer examination these regularly interstratified granite belts may at once be seen to change direction and to divide into side-branches, cutting transversally through the adjoining schists, which positively proves their intrusive nature. The narrower branch seams of the granite belts are usually imperfectly crystallized porphyritic, while the larger bodies are completely crystalline, composed principally of feldspar and quartz, with scantily interspersed chlorite in place of mica. The parts of the schist in immediate contact with the granite have sometimes suffered no visible alteration, but in other instances, for the distance of a few lines, the substance is somewhat altered, generally by change in color. This same locality, with its numerous granitic seams, exhibits also very beautifully the gradations of the schists from a well-laminated aphanitic mass into a massive crystalline dioritic, and the intersection of schists, diorites, and granites by other transverse dioritic rock-seams, which differ in appearance and composition very little from the conformably interstratified seams of diorite; but all of these rocks again are cut through by doleritic dykes, well distinguishable from the dioritic dykes by their dark blackish color.

South of these granite exposures, after having passed over some of the ordinary schistose beds, we meet in the succession with a belt of a banded, well-laminated quartz schist, inclosing within its mass an abundance of minute granules of magnetite, which, in certain of the narrow alternating seams of the banded ledges, amounts to fifty or sixty per cent of the rock-mass.

A number of test-pits, uncovering this rock-belt in this spot, and in others on the opposite side of the creek, were not rewarded with success in finding a commercially valuable deposit of iron-

ore; the strata exposed in the pits are frequently found in a much corrugated and distorted condition. The same ferruginous beds we find exposed in the rock-bluffs on the north side of Michigan Street, within the city limits of Marquette; they are contaminated there by a large proportion of iron pyrites, mingled with the magnetite On the north side of the ferruginous beds, dioritic schists adjoin, which merge with a bulky rock-mass of crystalline diorite, forming the north end of the bluffs. Two or three hundred steps west of this locality, we find, on Michigan Street, at its intersection by Front Street, between the dioritic schists, lenticular seams of calcspar and of sparry carbonate of iron; the ironspar is partly decomposed into a dark reddish brown friable ochraceous mass. The schists at this spot are very even bedded and hard, cleaving into sharp-edged rhomboidal fragments, which answer a good purpose in construction of road-beds, and are quarried there for use in the streets of the city. East of the bluffs, exposing the ferruginous and pyritous ledges, in the prolongation of Michigan Street, a low knob projects over the plateau land, consisting of interwoven crystalline blades of hornblende with a micaceous fissibility, and of a moderate proportion of red orthoclas crystals, besides an abundance of interspersed pyrites granules; the rock seems to be an analogon of the Picnic Island rock, and intrusive of the surrounding schists.

The so far described rock-series, characterized by its hornblendic composition, and therefore all of a dark green color, commences to change if we follow the succession of layers farther to the south. Lighter colors begin to prevail, and the schists become more fissile, slate-like, approaching clay slate in aspect, or else resembling novaculite. Some of the layers are intensely tinged with red oxide of iron, and irregular belts of hematitic iron-ore are interstratified with them. Such an ore-belt was one of the first discovered iron mines in the district—the Harlow mine, also called Eureka mine, situated on the north side of the Houghton and Ontonagon Railroad, only two miles west of Marquette; the mine is abandoned since the discovery of the much richer ore deposits farther west. Leaving the dioritic schist quarries on Michigan Street, and going south toward the slope of the hill above the Grace furnace, we pass on the way several quarries or pits in which lighter-colored softer schists of argillitic character are exposed, similar

clay slate-beds compose the bluffs above the furnace, varying in color from green to whitish, and from brown to red; some of them have a bright silky lustre from micaceous or hydro-micaceous scales, copiously mingled with the mass; at other times the micaceous component forms a coating over the cleavage plains like a varnish. Alternating with these beds are seams of cellulose, sometimes cherty and ferruginous quartz; they continue down to the lake shore, but are not well uncovered there. West of the described locality we find in Ridge Street, where it passes over a steep hill, exposures of similar argillitic schists near the south slope of the hill, and north of these a large belt of novaculite schists more than one hundred feet in width; then, after short interruption of the outcrops by sand-masses, farther north the dioritic schists follow, all dipping regularly northward. The novaculite belt is at this spot divided into two reuniting arms by a large body of an eruptive diorite of coarsely crystalline structure. The drift-polished, denuded surface of the novaculite exhibits everywhere a much corrugated and distorted condition of the ledges. The novaculite of these and numerous other exposures farther west on the range is a wax-like, yellow, fatty-feeling rock, thinly laminated, and often readily fissile into the thinnest semi-transparent leaves, which have a resinous lustre and a certain degree of flexibility; it consists of an amorphous or minutely granular feldspathic mass, intimately amalgamated with a soft talcy mineral, which I identify with hydro-mica. Other good exposures of the novaculite are observable on the hills occupying the N. half of the N.E. quarter of Sect. 22, joined on the north side by dioritic schists, on the south side by clay slates. We find them again in the low meadow grounds in front of the knobs of dioritic schists, near the S.E. corner of Sect. 16; from here continued exposures can be traced passing the south end of the previously described granite hills, south of the magnetic quartz schists. Farther west, a high ridge, composed of almost vertically erected ledges, projecting in steep bluffs, occupies the central part of the S.W. quarter of Sect. 16, and extends some distance beyond into Sect. 17. These ledges are a continuation of the schistose novaculitic rock-belt, which here, being richer in hydro-mica, has a bright silky lustre, and is often minutely corrugated; the schists are interstratified with quartzose seams and with ferruginous beds, which in

part have the quality of a good hematite ore; but in the numerous test-pits opened on this range no quantities of the ore could be found to remunerate mining operations. The south slope of this ridge is formed by slaty argillites in various modifications; on its northern slope dioritic schists become exposed. Near the foot of the south slope a row of low but very cliffy knobs borders it, which consist of a blackish, coarsely crystalline rock, closely related to the doleritic dyke-masses found in other neighboring places; but while in these a white glassy anorthic feldspar, in combination with blackish brown augite, composes the rock, we find in this other rock a flesh-red orthoclas prevailing over the anorthic feldspar, which is not missing in it altogether. This eruptive rock-belt extends across Sect. 16, from one end to the other, close to its south line. South of here, across the valley, we find the basal part of another high range of hills composed of argillitic, hydro-micaceous and ferruginous schists, with quartzose seams and lenticular belts of hematitic iron-ore, with sparry carbonate of iron, and sometimes also with masses of hard specular ore. The before-mentioned Eureka mines are opened in the rock-belt of this locality. The higher part of the hill-range is formed of dioritic schists and of massive diorite, but a large portion of its surface is covered by drift-deposits, which prevent an observation of the relative positions held by the different rock-beds. We find the slaty and ferruginous beds of the Eureka mine series still farther to the south in circumscribed patches in the north-west corner of Sect. 26, and farther south in the slaty knob close to the brownstone quarries we see them well exposed; another outcrop is to be seen in the N.E. quarter of Sect. 28; but as a general rule all the rock-outcrops within the space of two miles south of the dioritic hill-range, which commences with the cliffs of the Lighthouse Point of Marquette, are, with exception of those mentioned, of a dioritic character, more resembling the strata next south of the granitic rim of the basin than those pointed out by me as Eureka mine series. Beyond this interval of two miles, a marked range of quartzite hills, commencing with high bluffs near the mouth of Carp River, trends westward; the heavy compact ledges of the quartzite dip south and form with their edges a brisk escarpment toward the north, under which in various localities an outcrop of novaculitic schists can be observed, exhibiting the same dip to the

south as the quartzites. In the S.E. quarter of Sect. 29, Town. 48, R. 25, we find the said novaculites conformably underlaid by greenish or bluish slaty argillites in almost vertical position; and north of these, after short interruption of the outcrops, follow high bluffs of vertically erected ledges of dioritic schists, which inclose a belt of coarse conglomerate, principally composed of granite pebbles in intermixture with schist fragments, and recemented by the same material, and alternate with seams of crystalline massive diorite. Farther to the north the rock-beds disappear under the drift. West of this locality the quartzite range terminates abruptly, and for the distance of over four miles only diorites and dioritic schists can be noticed in the outcrops in that direction, until we strike Carp River, where, in the N.W. quarter of Sect. 33, Town. 48, R. 26, the quartzite reappears, forming a high hill-range, which follows for a while the south side of the river, and then bends more to the south-west, striking the north edge of Teal Lake. The dip of the quartzites is south; on the north side of the ridge the projecting ledges form high perpendicular walls, beneath which novaculites, and farther down the hill-slope schistose strata, resembling the schists of the Eureka mine, become largely exposed; some of them are copiously disseminated with granules of martite, or others intensely tinged with hematitic iron oxide; other greenish hydro-micaceous, and partially chloritic schists, are full of lenticular masses of carbonate of lime and of iron, more or less mixed with siliceous matter; and abundant quartz seams interrupt the uniformity in the succession of beds, which, farther north, in the embankments of the river, make gradual transition to the ordinary sort of dioritic schist, which compose the hills on the north side of the valley and present numerous exposures.

The description given thus far of a section across the dioritic rock-series of the Huronian group commencing on the north margin of the synclinal basin at the Dead River near the powder-mills, and continuing southward to the quartzite range, trending west through Sects. 35, 34, 33, and 32 of Town. 48, R. 25, has been a simple enumeration of the rock-beds succeeding each other in the indicated direction, without making an effort to reflect on the relative age of these strata. The general northern dip of the rock-series, from Dead River to Marquette Harbor, would indicate

the youngest age for the rock-beds farthest north, as they lean on and above the others; and as the oldest in the series, we had to take the novaculites and clay slates forming the southern hill-slopes near Marquette, as we see them there dipping under the dioritic schists; but we notice, farther south, dioritic rocks exposed corresponding lithologically with those north of the novaculite belt, and these succeeded again by argillitic and ferruginous beds, like those composing the bluffs at Grace furnace; still farther south we observe an inverted dip of the rock-beds, and see the novaculites and argillites next below the quartzite formation, which decidedly has a younger age than all the before-considered rock-beds. From these facts we must necessarily infer the existence of repeated plications of the strata exposed within this interval, and an overturned position of the northern part of the layers, as the novaculites and argillites underlying them are beyond doubt the equivalents of those seen on the south side next below the quartzite, and upon the dioritic layers, and represent the uppermost beds of the dioritic rock-group.

The drift-masses covering the largest portion of the surface of the land intermediate between Marquette and the southern quartzite chain, whose eastern terminal point bears the name Mount Mesnard, prevent the actual observation of the above suggested plications of the strata, and the recognition of a certain order in the distribution of the different rocks, which would enable one to determine the relative position which every one of the outcrops holds in the succession of beds. I shall therefore describe the rocks of this area merely with regard to their lithological characters, and the notation of their topographical location.

The rock-bluffs and small islands between the Cleveland ore-dock and the mouth of Whetstone Creek are principally composed of middling coarse-grained diorites, in which the component hornblende and feldspar crystals can be distinguished with the naked eye. The feldspar is in part red orthoclas, and epidote forms almost constantly part of the mixture, besides sparingly disseminated grains of iron pyrites, and sometimes copper pyrites. Epidote is also the filling material of small fissures in the rock, while in other cases it is red feldspar. The larger fissures are generally filled with quartz, or with a singular intermixture of fibrous quartz and epidote crystals, with addition of calcspar, which bands have

often the fibres arranged in transverse position to the walls of the fissures. Associated with these shapeless massive rocks are hard schistose beds of dioritic and chloritic composition, and other argillitic slates, with inclosed quartz seams, which slaty layers seem to belong to the upper Eureka mine-series. We see them well exposed in the quarries on the road to the North-Western Hotel, and still more extensively on the south side of the diorite knob at the mouth of Whetstone Creek, where a succession of several hundred feet of them, in all colors, as green, red, brown, bluish, and gray, forms the shore bluffs. In the quarries at the North-Western Hotel we see the massive, evidently eruptive diorites in discordant contact with the schistose beds. The diorite composing the promontorial knob at the mouth of Whetstone Creek differs considerably from the other diorite masses by a very fine aphanitic grain and a much lighter pale green color; its substance is often not entirely homogeneous, and exhibits, particularly on the weather-worn, drift-polished surfaces, lines marking a considerable corrugation and intricate distortion, as if differently shaded rock-doughs had been incompletely mixed.

The adjoining schists have participated in this corrugation, and both rocks are pervaded by a network of narrow seams of calcspar and partially of quartz, which serve as a cement for the fractured, shattered, less plastic portions of the disturbed masses.

West of this knob, on the south side of the mouth of the creek, the ground rises rapidly in stair-like, rocky offsets, to a height of 200 feet, and spreads then into broad undulating drift-covered highlands, which increase in elevation with their distance from the shore. The summits of these undulating lands are formed by numerous rocky knobs and short ridges, partly arranged in parallel east and west rows, partly in irregular scattered position, some of them not more than 20 feet high, others projecting as much as fifty feet over the general surface. One of the largest of these ridges commences with a conspicuous isolated diorite hill, situated at the south-west corner of Sect. 23; it is severed by a narrow ravine from the western continuation of the ridge, which follows the line between Sect. 22 and Sect. 27. In this and the other neighboring ridges or knobs, the main body is formed of a fine-grained rather light-colored greenish gray diorite in bulky non-stratified masses, usually surrounded by schistose beds of a dioritic

character ; but the schistose exposures are, in these localities, never very extensive, being, as the more destructible, softer material, removed from the surface by erosion of the exposed parts.

In case of their exposure, a general conformability seems to exist between the schists and the inclosed diorite masses ; but often we see, as in the above-mentioned instance, the schists adjoining a diorite mass completely entangled with it, in a mode which proves a high degree of plasticity of the diorite mass at the time the intermixture took place. The fine homogeneous grain of these diorites is more apt to preserve the traces of a former plastic condition, by a streaky and cloudy lineation of their substance, particularly visible on the exposed drift-polished surfaces, than is the case with a coarsely crystalline rock ; we notice it therefore in this range more frequently than in other localities, with outcrops of coarser grained diorites. Coarse-grained diorites are, however, not missing in this range ; they are generally darker in color than the finer grained rock. A few low diorite knobs in the S.W. quarter of the N.E. quarter of Sect. 27, Town. 48, R. 25, are middling coarse-grained, similar to the rock of the quarries at the North-Western Hotel ; much coarser is the rock in the diorite bluffs of Sect. 29, near the old county road to Negaunee, and in various other localities farther west. Particularly extensive are the dioritic exposures in Sects. 19 and 30 of the town presently considered, and in the adjoining sections of Town. 48, R. 26, which together form one compact body of the dioritic rock-series, crowded with rock-ridges, and not so much incumbered by hiding drift-masses as in the more eastern sections ; therefore a splendid field for examination is offered here to the observer. Although the general character of this large series of rock-beds is very uniform, as it regards the chemical composition, still an endless number of variations in their structure is produced by the different degrees of metamorphism to which these once indubitably sedimentary rock-beds were subjected. In bulk the schistose beds prevail over the massive rocks, which generally form parallel seams wedged in between the schists, sometimes in briskly changing contrast, much oftener linked with the surrounding beds by almost imperceptible gradations in the structure. From all facts which I observed, I must infer, the principal altering agent causing the transformation of the sediments into their present

form, has been heat in sufficient degree to allow selective crystalline arrangement of the sedimentary molecules in all of them, and to produce in a portion of them a partial fusion and emolliation, by which the sedimentary structure became obsolesced more or less completely. During the uplift of the superficial rock-crust, more by means of a laterally exerted pressure than by tension from below, the lower softened or even liquefied masses most naturally entered the sinuosities of the less altered beds raised into parallel folds, and consequently appear in the exposures as regularly interstratified alternating seams, while some of the completely liquefied mass occasionally found its exit to the surface through irregular transverse clefts in the covering crust contemporaneous with the general uplift, and therefore such dykes, originating from the same store of material as the larger diorite belts conformable with the formation, scarcely differ from them, except perhaps by a less perfect granular crystallization of the narrower, more quickly refrigerated transverse belts, than the slowly cooled bulky diorite masses have.

It would be tiresome for the reader, to give a lengthy description of all the different rock varieties which occurred to me in the examination of the presently considered area. I only take occasion here to make some remarks on the schists, generally called dioritic schists. Only the smaller portion of the so-named schists consist of the essentially important constituents of a diorite, of hornblende and feldspar, in a form discoverable with the naked eye ; many contain the hornblende in small microscopical crystals ; in other schists, which all consist of a feldspathic ground mass, chlorite replaces the hornblende, either partially or completely ; they are called chloritic schists, but in many of them chlorite is a very subordinate component ; but a large portion of schists belonging to this rock-series, and dark green-colored like the others, has a fibroso-micaceous, fatty-feeling mineral for one of its main constituents, which is probably hydro-mica, and not talc, for which it is frequently mistaken. They are softer and much more fissile than the true dioritic schists ; but as numerous transitory forms connecting these various kinds of schist exist, I have generally made no distinction between them, and have used the name dioritic schist for all the green-colored schistose members of

the dioritic group, with exception of clay slates, or others of a different specific character.

The dioritic rock-belt of the Marquette region extends in a width of about two miles for a long distance westward, but a part of it is covered by the younger members of the Huronian series. The general rock-character remains the same. Another already-mentioned area of dioritic rocks is displayed on the north side of Dead River. The strata in this western country are not so excessively dislocated as to be overturned, like those near Marquette ; they lean on the north side, with a southern dip on the granite formation ; and off from it, rarely an intrusion of granitic seams between them is observed. In the upper horizon of the dioritic formation in this western district, the schists frequently inclose brecciated or conglomeratic seams, as a part of the pebbles is angular, another rounded. Such conglomerates are well exposed on the north slope of the hills west of Deer Lake furnace. The pebbles are sometimes crowded, but often distantly dispersed through the mass ; the majority of them consists of granular, somewhat porous feldspathic substance, which on fresh fractures contrasts little from the surrounding schistose mass, but shows itself very plain on weathered surfaces, on which the pebbles turn white or pale reddish. The previously mentioned conglomerate masses, full of granitic pebbles of large size, found within the dioritic schists in the S.E. quarter of the S.W. quarter of Sect. 29, Town. 48, R. 25, belong to the same horizon ; but the likewise previously described much larger belts of a granite conglomerate found in the south part of Sect. 2, Town. 48, R. 26, interstratified with the schists, in close proximity to true granites, are much lower in the series. Other compact but distinctly laminated schistose rocks occupying about the same horizon, exposed on the hills east of Deer Lake furnace, are porphyritic by the segregation of an abundance of white feldspar crystals within a minutely granular feldspathic ground mass, colored dark green by intermingled chlorite ; with them occur more fissile schistose layers, inclosing red and white feldspar crystals copiously intermingled, besides considerable proportions of calcspar, which makes the rock effervesce with acids, and by exposure its surface becomes full of cavities.

Near the southern margin of the synclinal basin the dioritic rock-group rarely forms the surface ; the quartzite formation and

the iron-bearing rocks occupy it to the greatest extent, and come in many places in close contact with the granite, or are separated from it by only a narrow belt of schistose rocks, which, by interlamination of novaculite seams and of siliceous limestones in irregular wedge-like or lenticular bands, have some resemblance with the Eureka mine-beds, forming the top part of the dioritic series. In some localities, however, as in the bluffs in the south half of Sect. 25, Town. 47, R. 26, a large succession of micaceo-chloritic schists rests on the granite, while, further north, the iron-bearing rock series is found under the drift-covered surface.

Large insular bodies of diorite and of dioritic schists are found in the central part of the basin, where the iron-bearing rocks or other younger Huronian deposits form the surface. These dioritic rocks in the central part of the basin are by Major Brooks represented to be regularly interstratified belts of the iron-bearing rock series, forming part of the sedimentary succession. According to his statements, three distinct belts of such diorite occur. The first and lowest is said to be intercalated between his Groups VI. and VIII., both composed of siliceous and ferruginous schists. The diorite belt itself is called Formation VII. Another diorite belt is located as existing between Formations VIII. and X. The last is a likewise ferrugineo-siliceous group ; this diorite belt is called Formation IX. And finally, Formation XI., another imagined distinct diorite belt, is placed between Formations X. and XII., both iron-bearing rocks.

I consider this as a misapprehension, and am of the opinion that these different dioritic masses are a part of the second subdivision of Huronian rocks, which were forced through the incumbent younger rock-strata at the time the general dislocation of the rock beds occurred. They hold no definite position to certain rock-beds of the upper series and are, just as it happened, once in contact with one kind, another time with another kind of the beds, and frequently their contact with them is not conformable. The chemical composition and external aspect of these dioritic masses is absolutely identical with the lower rock-complex, and differs on the other hand so widely from the nature of the beds with which they are found interstratified, or rather interposed, that this latter circumstance alone makes it very improbable that so sudden and abrupt a change in the material of regularly succeeding sedi-

ments ever occurred three times in repetition ; particularly as a very close relationship exists in the material of the three interposed sedimentary rock-belts, which clearly indicates a slow progressive change in the deposits from below upward, if we think, for argument's sake, the intervening diorites eliminated, and consider the three sedimentary belts in uninterrupted continuity. The parallelism frequently observed as existing between the diorites and the adjoining rock-beds of sedimentary character does not prove anything like a regular succession, as the parallel plication of the entire rock-crust of this country, caused principally by a lateral pressure, offered all the eruptive masses much greater opportunity to enter the sinuses of the folds or the seams of bedding, than to find their way to the surface by rupturing the beds transversally.

By comparison of the diorite masses projecting like islands from the iron-bearing belt which covers the surface of the Negaunee and Ishpeming mining district, with the main belt of exposures of the dioritic group, we find in the first massive, well-crystallized diorites to prevail over the schistose portions, which in the latter compose the much larger bulk of the formation ; minutely granular or aphanitic diorites are almost unknown in the mining districts, while such composed of large hornblende crystals imbedded in a granular feldspathic interstitial mass are locally quite common, generally constituting a portion of larger bodies with a finer grain. In the course of description of the iron-bearing rock-strata, and of other members in the succession of Huronian beds, there will be often occasion given for further remarks on the dioritic formation by their contiguity with it in the outcrops.

A change of material in the sediments, first perceptible in the terminal layers of the dioritic series, represented by the bluffs near Grace furnace, or by the beds of the Eureka mine, is mentioned previously. Rising in the geological horizon, we see argillitic, ferruginous, novaculitic, and quartzose beds taking the lead ; hornblende, the typical constituent of the lower series, almost disappears, and the equally important feldspar plays a more subordinate part in the composition of the sediments ; finally, quartz becomes supreme over all, and for a while it is the exclusive deposit, accumulated in heavy layers, amounting to a great thickness, a proof that great changes must have taken place in the ocean-bed. I have partially given a description of the

above-mentioned transitory rock-beds from the dioritic formation to the quartzite formation ; but as the exposures of this series farther west are generally observed in connection with outcrops of the quartzite formation, I propose to make, in further considerations, all descriptive remarks concerning them jointly with the descriptions of the quartzite formation.

CHAPTER III.

QUARTZITE GROUP.

WE are already informed of the extension of a quartzite range beginning near the shore two miles south of Marquette, with a knob about 300 feet in height, called Mount Mesnard, and trending westward for about four miles, where it abruptly terminates ; and that, after an interruption of nearly five miles in distance in the same line of strike, another range of quartzite rises, and continues to the north shore of Teal Lake. The quartzite, after having formed there a row of vertical bluffs, is finally lost under the level of the water, but reappears again near the west end of the lake, and continues to be well exposed almost without interruption westward, to the inlet of Carp River into Deer Lake, and thence bending somewhat southward, bluffs of quartzite can be followed to the east end of Lake Cooper, (or near to the quarter-post on the south line of Sect. 32, Town. 48, R. 27.) where the rock is seen for the last time as a part of this range.

Approaching Mount Mesnard from Marquette, we first pass, on the west side of the iron-smelting works and of the gas-house, the valley of a creek, which is underlaid by horizontal beds of Silurian sandstone, extensively quarried at this spot and shipped to Chicago and other large cities as an excellent building-stone. Farther up in this valley we can see the sand-rock horizontally deposited into clefts existing between the vertically erected Huronian schists at the time the deposits formed ; and with some care hand specimens may be obtained, representing the two vertical schistose side-walls and the intermediate horizontally laminated sand-rock mass, all in one piece. South of the quarries a large body of drift-hills, very much cut up by deep ravines, is to be surmounted ere we come to the foot of Mount Mesnard, which up to two thirds of its height

is covered by the drift-masses, and even on its summit an abundance of scattered granite boulders and large blocks of the Silurian sand-rock show, in addition to the drift-polished surface of the quartzitic rock-ledges, that the débris of the glacier period passed freely over the summit. After ascension above the drift-covered part of the slope, the first outcrops noticeable are light-colored, rather gritty arenaceous novaculites, unlike the fatty-feeling novaculitic schists with resinous lustre cropping out on the hill-sides of Marquette. Their dip is south, nearly vertical ; next above, in conformable superposition, follows a belt of compact white or white and reddish mottled quartzite in thick layers, amounting to about 200 feet, which composes a separate summit elevation adjoined on the south side by a shallow depression about 150 feet in diameter, which space is occupied by a succession of argillitic and hydro-micaceous schists or slates. The south side of this depression is formed of another thick quartzite belt, which composes a similar crest parallel with the other ; the ledges of this latter are more thinly bedded and interstratified with ferruginous and siliceous slaty seams. Conformably superimposed on this second quartzite belt follows a series of siliceous reddish-colored limestones, interlaminated with hard novaculitic slaty seams of purplish color. This limestone formation composes the southern declivity of the hill, and projects in high vertical walls along the margin of the summit part ; some of the almost upright ledges, dipping to the south, are tilted over, and seem to have a northern dip. The much-corrugated limestone beds are full of siliceous seams, partially parallel to the stratification, partially pervading the rock in an intricate network, which seams, resisting atmospheric influences and the lixiviating action of water much better than the lime, project in sharp relief from the surface of the weathered rock, of which often nothing is left but the cellulose siliceous skeleton.

A short distance east of the summit of Mount Mesnard, the more thinly laminated quartzite strata, often ripple-marked on the surface and covered by a film of micaceous or hydro-micaceous scales, are quarried at the foot of the hill, to be shipped abroad for the use of hearthstones in construction of furnaces in Bessemer steel-works. By crossing this quartzite ridge, one and a half miles west of Mount Mesnard, on the line between Sects. 33 and 34, we find on the north slope of the hills, conformably beneath the

quartzite belt, outcrops of a coarse conglomerate in a seam of considerable thickness. The conglomerate, of dark purplish iron-color, incloses quartzite pebbles of white and red color, besides novaculitic schistose fragments of various tints ; they are cemented by a paste of similar schistose material, and intermingled with quartz-sand and octahedric crystals of martite. In connection with the conglomerate we find undisturbed beds of fine-grained novaculite schists, colored dark purplish gray by interspersed granules of martite, which sometimes become so abundant in the rock as to impart to it the quality of an iron-ore ; still I have never seen deposits of this kind large enough to give them practical value. The thick quartzite belt leaning on the south side of the conglomerates forms the summit part of the hill, which slopes slowly southward ; and then, at the opposite end of the succession of these large rock-masses, a deep ravine, following the trend of the strata, interrupts the uniformity of the descent by the steep rock-walls of its sides ; it is caused by the erosion of the belt of softer schists seen previously exposed between the two summit elevations of Mount Mesnard. The south side of the ravine is formed by reddish-colored quartzites dipping south in conformity with the other almost vertical rock-beds. The red quartzites are succeeded by a large series of siliceous, calcareous, and slaty beds, all more or less intensely red-colored by iron oxide. The limestones in this locality are partially much freer of siliceous seams than at Mount Mesnard, but still too impure to be used as a marble, or even for the purpose of burning lime. Having descended two thirds of the hill-side, the rock-ledges are found to disappear under the drift-deposits which form the base of the range and border the bed of Carp River in steep bluffs of alternating clay, sand, and gravel beds, which gravel is to a great extent cemented into a hard conglomerate scarcely distinguishable from the Silurian conglomerates exposed close by in the sole of the river-bed. Entirely analogous sections can be observed by crossing this quartzite ridge in any other place, but while observing the general harmony in the successive deposits, we learn at the same time how much the nature of certain layers can change in comparatively very short distances. I have crossed this ridge all along its extent at intervals of half a mile, and found in every instance considerable variations in the details of the section.

Arrived at the western end of the quartzite ridge, near the quarter-post on the north line of Sect. 32, Town. 48, R. 25, and close to a small lake situated in Sect. 29, just touching the line, we see the quartzite ledges with their incumbent limestone formation descend to the edge of a swamp, and disappear. Following the section line from the quarter-post westward, we come across this swamp. and have repeatedly to ascend and descend the interlocking drift-covered hill-spurs through which the ravine-like, meandering valley of Little Carp River winds its way. On the north side of our course we see high dioritic hills touching the creek valley with their base ; on the south side a broad belt of undulating plateau-lands extends. After a mile's travel, and having just emerged from the creek-bed crossing our way, we find at the quarter-post of the north line of Sect. 31 outcrops of the limestone formation, but no sign of the underlying quartzites to the north of the limestone exposures ; the surface is formed by drift, and not a great way off large rock-walls of diorite rise above it. The siliceous limestones alternating with slaty layers of purplish iron-colored tints continue to be exposed on the north side of the now widening valley of the Little Carp River to the north-west corner of the section, whence the formation crosses the valley and presents itself in conspicuous bluffs on its south side, as far as the Morgan furnace, and a short distance beyond it, where it is buried under the drift. On the opposite side of the creek, in this part of the valley, the diorite, covered at its base with a narrow talus of drift, rises to the height of 200 feet above the sole of the valley in briskly ascending rock-walls. East of the furnace the limestone formation composes several high knobs, which represent a succession of several hundred feet of strata in a nearly vertical position, and exhibiting considerable corrugation of the beds. The limestones are in part quite free of siliceous seams, some fine-grained with conchoidal fracture, others of saccharoidal crystalline structure, and certain beds contain large sparry crystals dispersed in a fine-grained calcareous ground-mass, which imparts to them the aspect of a porphyry. Their color varies in different shades of red or gray, or is variegated like Castile soap. While the Morgan furnace was in blast, the limestones were used as a flux with satisfactory results. Belts of cherty layers, of ferruginous argillites,

and of silky shining hydro-micaceous schists, are interlaminated with the limestone-beds in often repeated alternation.

Two miles west of the Morgan furnace, in the N. half of Sect. 33, Town. 48, R. 26, the previously mentioned high ridge of quartzite commences, which is supposed to be the continuation of the eastern quartzite chain, lost sight of at the quarter-post on the north line of Sect. 32, Town. 48, R. 25. The quartzites and associated rock-beds form a broad belt nearly a quarter of a mile in width. Thick compact ledges of whitish quartzite dipping south under a high angle, and amounting to a thickness of over 200 feet, form the south side of the hill, and project in large rock-walls; these are succeeded by an equally broad belt of compact, fine-grained novaculitic or argillitic slate-rock, of a dark purplish iron color, streaked by irregular seams or blotches of yellowish untinged slate substance; then follows again a large belt of light-colored compact quartzite and other slaty seams, alternating with thinner bedded quartzite ledges or belts of quartzite breccia occur in the succession; finally, schistose novaculitic strata, cropping out on the north slope of the range, signalize the lower horizon of the quartzose deposits, and beneath them the previously mentioned series of slaty argillites and hydro-micaceous schists, more or less charged with granular martite or with hematite, composes the base of the hill-side. In the east part of this quartzite range we found the quartzites on the south side regularly succeeded by the limestone formation; here, and west of here, no more of it can be discovered. Singularly, we find westward, all along the quartzite range, a large amount of limestone blocks mingled with the drift-masses, but no trace of the rock-ledges in place; the quartzites are on the south side of this hill-range overlaid by a large succession of slaty and arenaceous rocks, which have no similarity with the limestone formation or with the associated rock-beds.

Two miles farther west on this quartzite chain, near the east end of Teal Lake, is the location in which formerly a fine-grained compact novaculite was mined for manufacturing hone-stones of a superior quality. The strata are in that place several hundred feet thick, of fine grain and of even-bedded slaty structure; the greatest portion of the rock is dark graycolored, more of a clay slate nature; the seams, useful for hone-stones, are composed of a harder, more compact, and lighter colored material; but a large

proportion of these seams is spoiled for the purpose by numerous linear quartzose veins, and by specks of ferruginous substance. The large amount of waste rock to be dug out and handled in order to get a small quantity of sound and perfect pieces, made the business rather expensive; and after, by some unfortunate accident, the grinding and finishing shops erected at Marquette, near the mouth of Whetstone Creek, were destroyed by fire, the whole undertaking was given up as not sufficiently profitable.

Recently other parties made an attempt to mine hone-stones in Sect. 29, Town. 48, R. 25, but the prospects were not considered favorable, and the place was abandoned again.

Large and very instructive exposures of the quartzite formation and of its connection with the underlying dioritic series are observable at the west end of Teal Lake. The south slope of the hills is formed by a thick belt of compact, heavy-bedded, whitish quartzites, which project in long rock-walls, dipping southward under an angle of 65° to 70°; north of this belt we find dark-colored slaty rocks richly impregnated with minute crystals of martite in connection with seams of lighter-colored not ferruginous argillitic or novaculitic schists, amounting to considerable thickness; another thick body of quartzite ledges follows on their north side, which forms the edge of the northern slope of the hill-side, on which a descending section through the lower portion of the formation down to the dioritic series is well exposed; novaculitic seams alternating with bands of quartzite form the upper part of the slope; beneath them follows a large succession of silky shining hydro-micaceous slate-rocks, with a crystalline granular aluminous ground-mass in different shades of color, and in some of the seams charged with large proportions of granular crystals of martite and magnetite. These slaty rock-beds are on their north side conformably adjoined by chloritic and dioritic schists with inclosed massive diorite belts, which rock-series composes all the hill-ranges farther north to the valley of Carp River, and those on the north side of the valley. West of the exposures on Teal Lake we find in the bluffs bordering the west side of Carp River, near its entrance into Deer Lake, a coarse quartzite breccia, interstratified with the novaculitic and hydro-micaceous schists in the lower horizon of the series; this brecciated rock is not an accumulation

of rock-fragments variable in character and transported from a distance, but seems to be formed mainly of the shattered ledges on the spot, becoming somewhat intermingled and recemented by siliceous and ferruginous matter. If we follow the brow of the hills trending from there westward along the south line of Sect. 33 to the east end of Lake Cooper, the exposures of the quartzite formation become much more extensive. The quartzite formation forms here the basal girdle of a much higher mountain body of dioritic rocks, which occupies the central part of the above-named section; and here frequent opportunities are offered to see the intimate connection existing between the two groups, linked together by uninterrupted succession, and by gradations in the change of the material of the rock-beds.

A mile north-west of Lake Cooper is an isolated large belt of quartzites, which trends in north-east direction diagonally across the S.E. quarter of the S.E. quarter of Sect. 30, and the S.W. quarter of the S.W. quarter of Sect. 29, Town. 48, R. 27. The heavy beds of quartzite lean in highly inclined position with southern dip on the side of a ridge of serpentine, towering with precipitous rock-walls above its circumvallation by the quartz rock. A creek washes the base of the quartzite bluffs, and on the opposite southern side of the valley rises another serpentine ridge equalling the northern ridge in elevation. The quartzites are severed from the serpentine by a deep narrow ravine partially filled with talus, which prevents seeing the rocks in their immediate contact. The serpentine ridge on the north side is nearly a mile wide, very rugged, and cut up into a good many smaller parallel crests with intervening ravines. North of the serpentine a narrow belt of dioritic schists, with inclosed, imperfectly crystalline granitoid seams, follows as the adjoining rock, being well exposed near the N.E. corner of Sect. 30; thence northward much of the surface is covered by drift deposits; but south of the quarter-post, on the west line of Sect. 20, quartzites of granular arenaceous structure, partly full of rounded pebbles and conglomeratic, become exposed in association with porous micaceous, thinly laminated sand-rock ledges, greenish yellow or reddish brown, colored by iron oxide; their dip is northward. Farther north the surface rapidly declines and spreads into extensive marsh-lands, through which one of the head branches of Dead River winds its way; but a short distance

west of the S.E. corner of Sect. 18, in the midst of the marsh-lands, a low wave-like ridge projects, which is composed of alternating layers of a dark sand-rock and of black carbon-colored slates, dipping north. The entire marsh-land and the hills adjoining it are, as far as I could examine them, all underlaid by a similar black slate-rock, with inclosed sand-rock beds. The last-mentioned rock-beds are found to repose directly and conformably on the quartzite formation, in many exposures to be seen on the east and on the west side of this marsh; the south line of the S.E. quarter of Sect. 24, Town. 48, R. 28, passes over a hill of quartzite, exposed in high perpendicular walls, and overlaid on the north side of the hill by a very large succession of slate and sand-rock beds. A quarter of a mile south of this place, in the N.E. quarter of Sect. 25, is another ridge formed of thick quartzite beds, with some schistose novaculitic layers, which on the south side are in contact with the dioritic formation. Other large quartzite hills occupy the N.E. quarter of the N.E. quarter of Sect. 23, and the S.E. quarter of the S.E. quarter of Sect. 14, Town. 48, R. 28; likewise in association with novaculitic and hydro-micaceous schists, and conformably overlaid by dark slates and banded siliceous rocks, which contain in this latter locality a large percentage of iron oxide. Farther to the west I have not extended my examinations.

East of the above-mentioned marsh-land surrounding the headwaters of Dead River, the first exposures of the quartzites analogous to the quartzites of Teal Lake or Mount Mesnard are found in the N.W. quarter of the S.W. quarter of Sect. 21, Town. 48, R. 27, where a short but quite bulky ridge of quartzite leans with its beds dipping northward on the northern slope of a high serpentine ridge, which constitutes a part of the previously mentioned body of serpentine hills, although a swampy valley intervenes between them. North of this quartzite ridge we find a row of other knobs trending north-west, composed of the same rock, which occupies nearly the whole east half of the N.W. quarter of the section. On the east side of these quartzite hills we see the schistose beds of the underlying novaculite series at the surface, and these on their part to repose on dioritic and chloritic schists. On the west side and on the north side, the dark-colored arenaceous slate-rocks, identical with those forming the bottom of the

marsh-land, are seen to overlie the quartzite, amounting to a great thickness, and projecting in a separate row of hills with very steep declivity on their north slope. The last-mentioned quartzite outcrops are cut off by a swamp near the north quarter-post of Sect. 21 ; but by taking a north-east course we find them again in the centre of the S.E. quarter of Sect. 16, and from there we can follow the exposed ledges of the rock eastward almost without an interruption to the S.E. quarter of Sect. 14. Here the dioritic rocks, and soon after the granitic, commence to form the surface rock further on in this eastern direction ; but we can find the belt of quartzite outcrops continued by taking a north-east course, at a distance of not over a half a mile north of the quarter-post of the east line of Sect. 14 ; very good exposures are also at the quarter-post on the east line of Sect. 13, at which latter place the direct contact between the granite and the quartzite is plainly observable. From that locality we can follow traces of this rock-belt all along the north side of the granite range trending eastward, and find it well exposed again in the north part of the S.E. quarter of Sect. 17, Town. 48, R. 26, near the coal-kilns and the tram-road of the Morgan Furnace Company, at which place coarsely brecciated seams are seen interlaminated with the other compact ledges of quartzite, leaning with northern dip on the granite hills ; and above the quartzite, follows in uninterrupted succession, a large series of more thinly bedded flaggy layers of a micaceous and ferruginous sand-rock alternating with slaty rock-seams. The slope of the granite range is farther to the east much incumbered by drift deposits which hide the quartzite formation ; but as the next incumbent, arenaceous and slaty rock-beds are constantly exposed in this direction in the bluffs of Dead River, I suppose it to continue eastward as far as the centre of Sect. 14, Town. 48, R. 25, at which locality heavy masses of compact quartzite underlie the said arenaceous rocks, and repose directly on the granite which composes the summit of the hill range on the north side of Dead River. In this northern belt of the quartzite formation, in anticlinal position with the Teal Lake quartzite range, the lower novaculitic horizon of the group has rarely been noticed in the exposures, with exception of those mentioned as occuring in the west half of Sect. 21, Town. 48, R. 27, where this part of the formation, consisting essentially of the same argillitic and hydro-micaceous

material as in other localities, is a harder, more compact rock, delicately marked with linear striæ of lamination, but not always very fissile in this direction, cleaving sometimes into rhomboidal, but often into very irregular fragments, contrary to the lamination. The color of the rock varies from light greenish white to drab or brown, or from light reddish tints into a blackish purple ; generally narrow seams of various colors alternate with each other. The dark purplish seams are richly impregnated with granular crystals of martite, or also magnetite, and often we see the ledges extremely distorted and corrugated by their upheaval. The visible thickness of the exposed ledges amounts to more than 300 feet ; upward in the succession, the intercalation of quartzite seams connects them gradually with the quartzite formation, and descending, we see a similar gradation and connection with the schistose part of the dioritic series exhibited by the increase of chlorite in the composition of the ledges, and by their change in structure from a regular banded sedimentary lamination to an irregular schistose or slaty lamination independent of the sedimentation. In this locality the intersection of these novaculitic schists by a large doleritic dyke is likewise to be observed, of which I intend to give a more explicit description in the subsequent chapter on eruptive volcanic rock-belts.

Returning to the shore, three miles south of Marquette, we find the south side of Carp River valley likewise formed by high quartzite ridges, larger in extent than those on its north side. The intermediate space of the valley is generally covered by drift deposits, and beneath them by Silurian sand-rock, which is in several places denuded in the bed of the river and in the bluffs at the shore. The quartzite formation comes also to the surface on this space at and near the shore line, on the south side of a small creek which enters the lake not far from the supposed N.E. corner of the S.W. quarter of Sect. 36, Town. 48, R. 25, whose place is in the lake. The white compact quartzite ledges, in a nearly vertical position, barely project with a rounded drift-polished surface from the edge, and from the top part of a drift terrace. A spur of the outcrops forms a small rock promontory projecting into the lake, at which locality the discordant superposition of the Silurian sandstones and conglomerates on the upright quartzite beds, and into the clefts existing between them, is well exhibited. In a

quarry opened in the bluffs near the creek-bed, fine slabs of quartzite can be obtained, covered with micaceous scales, and wrinkled on the surface by ripple marks. The high ridge of the quartzite formation commences close to the shore, and exactly in the N.E. corner of Sect. 1, Town. 47, R. 25. The rock-bluffs on the roadside exhibit a well denuded section across a synclinal trough of the formation, which is already described in former Reports on the Upper Peninsula by Major Brooks and myself. I briefly repeat it here. Commencing the examination from the north side, we find at first a large succession of white quartzite beds exposed on the lower levels near the roadside ; their dip is south. Next south of them follows, with conformable dip, a large series of purplish gray-colored novaculitic and argillitic schistose and slaty layers, interstratified with seams of red quartzite and of cherty beds ; upward in this rock-belt calcareous bands begin to appear in the alternation of beds, and finally a thick belt of siliceous limestones terminates the succession. The limestones are considerably corrugated, which corrugation becomes very conspicuous on weathered faces of the rock, on which the siliceous seams parallel with the stratification stand out in high relief. Besides the general corrugation, the entire body of limestone ledges is bent into a central synclinal trough, to which all the other rock-beds adapt themselves, so that by going farther south all the previously described strata occur again in an inverted order, and dipping north. The large quartzite belt forming the southern margin of the synclinal arch composes the highest crest of the range. In a ravine on the south side of this quartzite belt, much-corrugated silky-shining hydro-micaceous quartz schists become exposed, which conformably underlie it ; but the opposite side of the ravine is formed of dioritic and chloritic schists inclosing belts of granite, which are in anticlinal position with the quartzites and hydro-micaceous quartz schists.

In the bottom of this ravine a dyke is seen to intersect the dioritic schists and the hydro-micaceous quartz schists transversally, which consists of a rather light green-colored, middling fine-grained crystalline diorite. Farther south all the rock exposures disappear under the drift. The described bluffs near the lake shore are the truncated end of a large mountain ridge extending for many miles westward. Near the shore its height is about 150 feet, but farther

west its elevation increases to 700 feet ; its top part is divided into multiple parallel smaller crests and rows of knobs, of which many are perfectly denuded of soil and vegetation ; the folded condition of the beds, together with their imperfect denudation, is often a serious obstacle to the recognition of the true order of things.

For the first three quarters of a mile west of the shore, the dark purplish argillitic and lighter-colored novaculitic schists, and other rock-seams described as the second rock-belt in the above given section across the synclinal trough, compose the north slope of the ridge. These schists form rather compact rock-belts, and are not very fissile ; the interlaminated seams of quartzite, partly of red. partly of white color, are sometimes shattered into small angular fragments and recemented into a breccia by a dark red iron-colored quartzose substance ; narrower seams of very fissile hydro-micaceous schists and of siliceous limestone are particularly confined to the upper horizon of the exposed belt. North of this hill-slope, where the large quartzite belt with southern dip should be expected in the outcrops, the whole surface is deeply covered by drift deposits ; looking south, we see ridges of quartzite all along, which represent the south margin of the synclinal fold ; consequently their ledges dip north. Proceeding along the north margin of the range farther west, we have to descend into the ravine-like bed of a previously mentioned small creek entering the lake near the centre of Sect. 36. On the opposite side of the ravine we find no more of the schists. All the cluster of knobs before us consists of quartzite beds folded into bubble-like anticlinal hillocks and synclinal intermediate depressions ; wherefore almost every exposure exhibits a different local dip. Over the summit of the highest of these quartzite knobs, the west line of Sect. 1, Town. 47, R. 25, runs, and at the foot of the knob the north-west corner of the section is located in the bed of a western branch of the creek we had passed in the ravine a short time before. Turning here southward, following the section line between Sects. 1 and 2, we descend from the summit knobs to a level more than 100 feet lower than we had been, and come, near the quarter-post, to a wave-like transverse elevation trending along the hill-slope, which is composed of granite, inclosing irregularly wedged-in belts of chloritic schists, disrupted in their continuity ; besides, we see the granite intersected by two kinds of volcanic dyke-masses, one of dioritic,

the other of a doleritic rock character. In close contact with this granite, and scarcely distinguishable from it, we observe easily disintegrating rocks, composed of vitreous quartz-grains mingled with a smaller proportion of red feldspar crystals, cemented together by a semi-transparent, fatty-feeling, pale yellowish-colored fibroso-scaly hydro-mica, usually mistaken for talc, but not of magnesian composition. As an additional constituent of this rock, sometimes also chloritic scales occur in limited proportion. Here is the locality cited on a former occasion, to give an example of the transformation of sedimentary strata into a granite-like rock, by being exposed to the contact with eruptive granite masses, which is fairly illustrated by the mentioned natural section through the centre of a quartzite knob, composed of ledges raised into a large bubble-like arch, in the centre of which we see lowest the granite, and above it a series of gradations from the most altered granitoid condition to the ordinary white homogeneous layers which form the top of the arch. Among the upheaved lower ledges of the quartzite group, we recognize in this locality the hydro-micaceous quartz schists exposed in the bottom of the ravine near the lake shore, which from there up to this place can be traced all along the brow of the hill-range; they differ from the altered granitoid rocks merely by a more laminated schistose structure, and by a greater proportion of hydro-mica in their composition. Other black slaty rock-beds are noticed in this association, which contain a large proportion of small magnetite crystals sufficient to give to some of the seams the character of an iron-ore, but I could not see enough of them to determine their practical value.

A row of other large quartzite knobs extends in a south-western direction from the presently described locality to the west line of the S.W. quarter of Sect. 2. They are adjoined on the south side by granites in connection with dioritic schists; their north-western slope forms the circumvallation of a deep kettle-shaped depression, whose bottom is occupied by a small lake. The north side of this kettle valley is likewise formed by a barrier of quartzite hills in synclinal position with the south range; the inside slope of this oval-shaped valley is composed of the upper slaty division, and of the siliceous limestones, succeeding above the quartzites, on which they lean in an almost vertical position on both sides. Like in the eastern exposures, this rock series is formed of compact, fine-grained, dark purplish-colored argillitic and partly novaculitic schists, variegated with light-colored streaky seams, or spotted by irregular blotches devoid of pigment, in alternation with quartz or chert seams, and in the upper part with thick belts of siliceous limestones of reddish color. The lake has its outlet northward; through a crevice in the rock-wall it sends a small stream, rushing with velocity over the hill-slope, down to the Carp River. Beneath the quartzite wall inclosing the little valley from the north side, the lower novaculitic schists come to the surface on the northern slope, forming a belt of considerable thickness; they are very fine-grained, of a wax-yellow color, and quite fissile, with even surfaces of a fatty lustre. I take occasion in this place to point out the great lithological similarity between some beds underlying the quartzites, and others above them which have the essential qualities of a novaculite. It is for this reason frequently difficult to determine the horizon to which they belong, if their relative position to the quartzite cannot be seen. Lower down the hill-side, the little creek, after it has passed over the novaculite ledges and some intermediate quartzite seams, flows over dioritic rocks (partly schistose, partly massive and crystalline), while it crosses the north line of Sect. 2 not far from the quarter-post, and for some distance lower down; but the basal portion of the hill is deeply covered by drift deposits, and the creek carved its way to the river through them, high above the solid rock-ledges underneath.

The above-mentioned exposures of dioritic rocks in the creek-bed can be traced westward for the distance of half a mile to the bed of another creek in the N.E. quarter of the N.W. quarter of Sect. 2, where it embraces between its terminal furcation a knob of massive coarsely crystalline diorite, well denuded on the summit; it projects at the foot of steep quartzite bluffs, which form the higher part of the ridge. This is, to my knowledge, the only exposure of diorite in the main valley of Carp River for the distance of eight or nine miles west of the shore of Lake Superior. Returning to the little lake on top of the quartzite range, we can follow a belt of the slaty and calcareous rock series westward across the centre part of Sect. 3 and into Sect. 4. A high chain of quartzite hills towering above the south side of Carp River valley forms its border on the north side; on the south side the granite

formation comes close up to the slaty or calcareous formation, sometimes directly adjoining it; in other places a belt of quartz ite intervenes. The whole south half of Sect. 3 and the southern quarter of Sect. 2, Town. 47, R. 25, are formed of granitic rocks. Fine exposures of flesh-red fine-grained limestones can be seen a quarter of a mile west of the centre of Sect. 3 in the forks of a creek which flows into Carp River; following the bed of this creek downward to the river, we find the rock-beds mostly covered by loose débris; but occasional outcrops of siliceous schists and of iron-colored slate rocks, analogous to those connected with the limestone formation, seem to prove the extension of this rock-series through this gap in the range down to the Carp River. It unites there with the equivalent rock-beds covering the south slope of the Mount Mesnard quartzite range on the opposite side of the valley, in which from here upward, for a distance of three miles, only the beds belonging to this upper horizon of the quartz-ite series can be found in the outcrops which sometimes occur in the river channel, while generally all the bottom and sides of the valley are covered by drift. A quite extensive exposure of ferruginous slaty argillites in the embankments of the river is seen at the falls, situated a quarter of a mile south of the adjoining north corners of Sects. 4 and 5, which exposure continues for some distance above and below the falls; not far above them we find thick ledges of siliceous limestone interstratified with the ferruginous slates.

Desiring to describe the geological features of the country in a topographical order, I have to lead the reader back to the summit of the hill-range, near the west line of Sect. 3, where I mentioned the occurrence of limestone outcrops in the fork of a creek. Taking from there a due west course, we notice some distance ahead a high ridge trending from north to south through the east half of Sect. 4 into the north part of Sect. 9. As we ascend the slope of this ridge, the silico-calcareous strata we were on continue to be the surface rock for a part of the way, but rising higher we find the summit formed of heavy ledges of white quartzite in almost vertical position; and past the crest, on the opposite slanting side, incumbered with drift, the granite crops out in various places. The highest point of this quartzite ridge is formed by a knob situated on the south line of the S.E. quarter of the S.W.

quarter of Sect. 4. Going west from there along with the section line, we make a rapid descent over the cliffs of quartzite to an offset in the hill-slope, whose basal part is formed by still bolder vertical cliffs bordering a small lake, which are composed of a large eruptive mass of a crystalline dolerite. The opposite side of the lake is likewise lined with steep bluffs of the quartzite on the terrace-like top of which we find the S.W. corner of the section. The S.E. corner of Sect. 4 is located on granitic hills, which there come in close contact with the quartzite formation on the west side; south of this corner the line between Sects. 9 and 10 passes over several parallel undulating ridges ere it intersects a lake which covers the whole east half of Sect. 9. These ridges are all composed of granitoid rocks, but the most southern one bordering the lake is not a true granite, and evidently represents sub-conglomeratic altered strata of the quartzite formation, resembling by their hydro-micaceous composition a protogine. A swampy valley connects the large lake in Sect. 9 with the smaller one near the S.W. corner of Sect. 4, which receives the surplus water of the other and gives rise to a creek flowing into Carp River through a ravine-like valley carved into the drift-covered hill-slope, at times deep enough to denude the upper schistose ledges of the quartzite formation, of which the whole surrounding country seems to be composed. We pass over such silico-ferruginous slaty rock-beds with intercalated limestone belts, if we follow the section line northward from the S.W. corner of Sect. 4 to its intersection with the Carp River at the falls; the line west of the corner leads over almost inaccessible limestone bluffs, across two high knobs composed of this rock-series, and thence down to the bed of Carp River, where slaty members of the same group are locally exposed; finally, examining the line between Sects. 8 and 9 from the corner southward, we pass 200 steps from the corner over a small creek running east into the little lake, ascend then a high quartzite hill, descend into a depression, declining west, toward Carp River valley, and ascend again over the steep side of a granite hill, on whose brow we find the quarter-post located; thence we step over undulating drift-covered plateau lands a quarter of a mile wide, and stand on the edge of the south slope of the hill-range, which is very steep, full of granitic cliffs and intermediate ravines; climbing down over them, we find, about 300 feet below, at the foot of

the slope, the south corners of the two adjoining sections located on a small hillock of granite ; farther to the south, as far as the eye can reach, all is one large sand-covered plain, overgrown with pine, or in places totally deprived of trees by former devastations of fire. This range of granite, fully a half mile in width, is not much over a mile long ; it commences near the centre of Sect. 9 on the west side of the lake in the east half of the section, and terminates in the west half of Sect. 8 by sloping down to lower levels, covered by drift, or formed of the upper calcareous and slaty division of the quartzite formation, which I will call, for brevity's sake, *marble series*.

On examination of the western Sects. 7 and 12 and 13 of the adjoining Town. 47, R. 26, we find the marble series to be their only surface rock, with exception of very few spots in which the lower quartzite beds are exposed, as, for instance, on the hill-tops crossed by the north line of Sect. 7, and at the base of the rock-bluffs in the south part of Sect. 13, or in the hills occupying the N.W. corner of Sect. 12. The south-east quarter of Sect. 11 of Town. 47, R. 26, has likewise the marble series for its principal surface-rock, with good exposures near the quarter-post on the west line of the section. The rockspur projecting into Goose Lake, at the S.E. corner of Sect. 14, is the most westerly exposure of marble-beds in this district ; four miles north of it are the marble hills of Morgan furnace. The abrupt termination of this group of rock-beds, which in all the eastern exposures conformably succeeded the quartzite formation, is very strange, as we notice here at once, and in close proximity with the other outcrops, a totally different sort of rocks conformably resting on the same identical quartzite formation, without a sign of an existing gradation from one into the other kind of the incumbent layers. The calcareo-siliceous rock-series, exposed in conformable superposition on the quartzites, amounts at the south-east end of Goose Lake to from 200 to 300 feet, while we see at the N.W. end of the lake a still larger succession of rock-beds resting on the quartzite in apparent conformity ; but its composition and general aspect are in striking contrast with the first, and no one will consider the two sorts of sediments for a moment as equivalents. The latter silico-ferruginous strata, which have a large surface extent in Carp River valley, north of Goose Lake, are considered as a separate sub-

division, as Group V., and shall be more explicitly described in one of the following chapters. I continue therefore the description of the quartzite group, as it presents itself in the territory west and south-west of Goose Lake, and in some other localities not yet described, situated on the north and on the east side of the lake. In the N.E. quarter of Sect. 24, Town. 47, R. 26, a cluster of low quartzite knobs projects from the sand-plains through which the Escanaba River flows after its outlet from Goose Lake. The plains generally seem to be underlaid by granitic rocks, which come to the surface in some hillocks close to the Escanaba Railroad, in the centre of the south line of the above-named quarter-section, while the quartzite hills are intersected by the north line of it. The latter are noteworthy on account of the interlamination of ferruginous hematitic schists, and of tolerably fair seams of a schistose specular iron-ore with the quartzite beds, but the amount of good ore is too small to pay for its being mined. A short distance north of these hills, at the foot of a higher hill-range, the quartzites, overlaid by siliceous limestone beds, are extensively exposed. On the north side of Goose Lake, a quarter of a mile east of the N.W. corner of Sect. 14, a row of quartzite hills occupying the whole west half of the S.W. quarter of Sect. 11, strikes the shore in a north and south direction ; the beds are nearly vertical, or dip west-south-west. A broad swamp valley surrounds them from the east and north side ; north-east of the hill-range a string of lower hills, all surrounded by the swamp, occupies the north half of the S.W. quarter of Sect. 11, which is found to be composed of the upper limestone formation. West of the quartzite hills is a depression which separates them from a much higher hill-range trending parallel with them from north to south through the centre part of Sect. 10 ; its summit and main body are composed of dioritic rocks, but both sides of its base are formed of the silico-ferruginous rock-beds of the fifth group previously mentioned, which beds also fill out the whole interval between the two ridges, and lean directly on the west side of the quartzite range. North of the swamp valley a still larger body of quartzite hills covers the entire north half of Sect. 11 ; the strata of this range dip north under a high angle, and are on the north side overlaid conformably with the beds of the fifth group.

A large body of hills west and south-west of Goose Lake is ex-

clusively formed by the quartzite formation and its subordinate layers, of which the entire surface of the Sects. 21, 22, and 23, Town. 47, R. 26, is formed, besides a large portion of the adjoining sections on the north and south side. This mountain body is cut up by ravines and valleys into countless knobs and smaller ridges, which in a general way are arranged in parallel rows, trending east and west. Usually the strata are found in an almost vertical position, and exhibit such a variance in their dislocation, or are so imperfectly denuded, that even after a careful examination often much doubt remains about the order in their succession, and frequently one is obliged to determine in an outcrop what is above and what below in the series, more by inferences from the lithological quality of the rock than from its relative position to the other beds.

The basin of Goose Lake indicates evidently the spot of a great break in the continuity of the rock-beds and their faulted dislocation. On the north side of the narrow linguiform prolongation of the east end of the lake, near the S.E. corner of Sect. 14, we see the limestone beds in comparatively slow southward decline sink below the water level, and find on the south side of this lake arm, at a distance of 250 steps, different rock-beds, dipping in an opposite direction, under a very high angle at that spot, but the same ledges are, farther west at the coal-kilns, locally almost horizontal. If we follow the section line between Sects. 23 and 24 from the lake southward, we have to ascend almost inaccessible bluffs of dark gray slaty rock-beds in nearly upright position, and amounting to a great thickness. The substance of the slates is a finely granular or scaly crystalline aluminous silicate, easily cut with the knife and more or less fatty to the touch, and either of silky or waxy lustre, or in others more dull, novaculitic, or earthy in appearance ; their gray color is due to an abundance of minute magnetite crystals disseminated through the mass ; but seams occur which are entirely free of it, and are pale yellowish-white ; a seam of this kind is exposed near the water-house on the railroad track. The cleavage of all these beds is oblique to their sedimentary lamination. South of this belt of slate rock, which forms a terrace on the hill, a thick belt of white compact quartzites, about 100 feet wide, follows, projecting with vertically erected ledges in walls 40 or 50 feet in height, which form the summit of a front ridge of the

large body of hills ; fissures in the quartzite, filled with large-leaved micaceous iron oxide, are here quite abundant. South of the quartzite is a depression, on the other side of which reddish quartzite layers in alternation with blackish gray compact argillitic, or novaculitic, delicately laminated rock-seams follow each other in a broad belt, which composes a second undulation of the hill-top. The dark color of the schistose rocks is due to the intermixture of a large proportion of minute granules of magnetite, or also martite in octahedric crystals, and their ground-mass is the same granular aluminous silicate of a talcy blandness which composes the schists on the north slope of the hill-range. Proceeding farther south, we come across another depression to a third undulation of the surface, edging the south slope of the mountain body, which is composed of another quartzite belt, differing in character from the former quartzites by the altered granitoid structure of its beds, composed of coarse vitreous opalescent quartz-grains in intermixture with flesh-red feldspar crystals, and cemented by the hydro-micaceous scaly or fibroso-granular mineral previously mentioned as a component of the altered lowest beds of the quartzite formation in other localities. Quartzite ledges of the ordinary compact and homogeneous kind are associated with the others, and are interlaminated with seams of schistose, specular, and hematitic iron-ore analogous to the ore-seams mentioned in the quartzite knobs of Sect. 24. In the same horizon occur also brightly shining mica schists, identical with the corrugated glistening schists exposed beneath the quartzites, near the shore of Lake Superior, in the bluffs north of Harvey's furnace. On the south side of these mica schists a large belt of black, thinly laminated but compact schists, similar to the dark schistose rocks composing the central ridge, but still more richly impregnated with magnetite than they are, forms abrupt walls and shorter cliffs along the hill-slope almost down to its base, where sandy pine-plains expand, on which the granite comes to the surface in isolated knobs, one of which is crossed by the section line we follow, some hundred steps before we arrive at the south corners of Sects. 23 and 24. All the strata of the described cross-cut through the range are nearly vertical, and it is difficult to determine whether the beds represent one continuous succession of more than two thousand feet in thickness, or whether plications exist, causing a repetition of the

strata. Examining a cross-section through the centre of Sect. 23, parallel with the other, we find the rolling terrace land on which the coal-kilns are built formed of the same slate-rocks as in the first; some drift-polished larger rock-exposures are particularly favorable for a detailed study of the different seams in the succession. South, on the slope of the higher hills, we find similar slate-rocks continued in association with curiously mottled dark purplish gray silky-shining schists, full of angular small dots like the decomposed earthy residue of former crystals, colored reddish brown by the higher oxidation of the magnetite crystals, which give color to the whole mass. This schist contains also small streaky seams of a pale waxy color, semi-transparent in thin splinters, of fine granular texture and almost talcy softness, which are evidently formed of the same material as the dark portions, colored by magnetite, but have in this form all the qualities of agalmatolite, and prove by chemical examination to be an aluminous silicate, and not a magnesian. Farther south the large quartzite belt of the previously described cross-section follows, and all the subsequent beds in the succession correspond with the former, not in all particulars, but in a general way. About in the centre of the section we have reached the summit undulation of the range, and commence the descent over the south slope. We find here micaceous quartzite beds crowded with small octahedric crystals of martite, and dark, much-corrugated, silky-shining schists, similar to those which we found on the north slope in the same cross-section, which indicates a plication and repetition of the strata; lower down the hill the mica schists and compact dark schists, charged with octahedric iron oxide crystals, besides other flaggy ferruginous beds form the basal part of the slope, as they did a half mile farther east. At the base we find a swampy strip of land, beyond which, farther south, a rounded knoll rises, which is composed of quartzite beds of granular and well-laminated sand-rock structure, in alternation with flaggy arenaceo-ferruginous beds, and with seams of iron-ore partly in the coarsely crystalline form of granular specular ore, partly in the schistose form of slate-ore, all of very bright metallic lustre. In the lower part of this ore-bearing rock-series, in a nearly vertical position, with northern dip, the ore-seams are associated with dark green chloritic schists, inclosing crystals of iron garnets, which rock has much resemblance to the chloritic rock found with

the ore deposits of the Michigamee mines. This is the location of the Gilmore mines, situated close to the south quarter-post of Sect. 23; they are not worked at present. South of the mines is the large swamp valley of a tributary of the Escanaba River; a short distance east of them, the granite, with inclosed belts of schistose hornblende rock, is well exposed in a cluster of hillocks projecting over the sand-covered plains near the base of the high quartzite range. We have examined now two cross-sections of this range—one along the east line, another through the centre of Sect. 23; a general correspondence between them is obvious, and the same is found true if we examine the range a half mile farther west, along the west line of Sect. 23. We find the north-west corner of the section on the drift-covered slope of the same range, which has lowered here, and expands into a rolling high plateau. The large quartzite belt composing the brow of the summit farther to the east is here exposed in the ravine-like bed of a creek, and with it, interstratified beds of schistose, hematitic, and specular iron-ores similar to those connected with the quartzites near the south slope of the range on the east line of the section. Analogous ore-seams, interlaminated with the quartzites, occur a mile farther west in the N.E. quarter of Sect. 21, at which locality considerable work has been done by explorers, but with no success; the ore in any of these places is too siliceous to be marketable. South of the quartzite exposures in the creek-bed, on top of the plateau, we find them succeeded by schistose, novaculitic, and argillitic beds, interlaminated and alternating with quartzose belts, part of which constitute a coarse breccia. Numerous small knobs projecting over the drift-covered, undulating level offer a chance to observe the denuded succession of these ledges, continued without a material change of character as far as to the quarter-post of the line, which is situated on the south slope of the range in a depression between high ridges formed of quartzites, partly in homogeneous, compact ledges, partly in a granitoid form, composed of a granular mixture of quartz and feldspar, cemented by interstitial seams of hydro-mica, as we have noticed it before in the more eastern exposures on the south slope. The high hill north-west of the quarter-post is partly formed of a coarse breccia of hard, steel-gray, ferruginous slate fragments, in intermixture with angular pieces of red and white quartz and of novaculite, partly of solid,

unbroken ledges of quartzite and of slate-rock. South of this summit ridge are several parallel rows of rock-crests and knobs trending from south-east to north-west across the south half of Sect. 22, composed of a very coarse granite breccia inclosing blocks of large size several feet in diameter, cemented together by an arenaceous and chloritic interstitial mass of a laminated, evidently sedimentary structure, which exhibits itself plainly in some portions of the rock, in which the rock-fragments are more thinly scattered through the cementing ground-mass. In certain portions of these knobs the granite appears in solid masses, too large to be taken for fragments pertaining to the breccia, which fact induces me to suggest the nucleus of all these hills to be a solid granite mass, whose shattered surface portions are recemented on the spot by sedimentary débris washed into the interstices. A parallel ridge next south of these narrow, very abrupt ridges of the granite breccia is composed of hard, fine-grained steel-gray slate-rocks, partially with silky lustre, and of a large belt of quartzite, which forms the south side of the hill, both rock-belts adjoining each other in a nearly vertical position. A swampy interval separates this ridge from one farther south, composed of greenish-colored micaceo-chloritic sand-rock beds, partially compact, quartzite-like, partially porous, like ordinary sandstone ; seams of this very thick succession of beds are conglomeratic. The inclosed water-worn pebbles are in part granite, in part slate fragments. This ridge forms the edge of the hill-lands, and slopes down to the swamp plains and level pine-lands, through which the east branch of Escanaba River winds its way. The rock character of this last ridge does not differ much from the rock-series of the Gilmore mine, although no seams of ore are found in it so far ; but from one place to the other along the railroad track, almost uninterrupted outcrops of related rock-beds can be observed, of which some are intensely impregnated with hematitic iron oxide ; the dip of all these beds is northward, nearly perpendicular. As every locality exhibits different features of a formation, I will describe another cross-section from north to south along the west line of Sect. 22, Town. 47, R. 26. The north-west corner of this section is some distance below the summit on the north side of the western terminal hill of the same quartzite range, whose eastern end was the starting-point for our present examinations of the quartzite formation. The north slope of this hill is covered with drift, and has along the line north of the corner no outcrops, but farther west bulky quartzite ledges are exposed in the ravines.

South of the corner, 150 steps up-hill, gray conglomeratic quartzites project in low cliffs ; farther on, larger exposures of hard, dark gray slates, in alternation with quartzite belts, are met with. The summit is formed by heavy beds of white and red mottled quartzite inclosing bunches of micaceous iron oxide ; the strata dip north under an angle of 70°. A short distance west of the line are the previously mentioned test-pits, in which seams of schistose, hematitic, and specular ore, interstratified with the quartzite, are well uncovered. Descending the south slope, we notice slaty seams like the former, seams of novaculite and of quartzite alternately succeeding each other, and a short distance east of the line brecciated rock-masses are exposed in high perpendicular walls, which consist of intermingled slate and quartzite fragments ; another portion of these cliffs consists of compact reddish quartzite. Lower down, the slope is not so steep, and outcrops are less abundant, but we find the quarter-post situated on a belt of quartzite ledges, close to a small creek, on the south side of which rises a high ridge composed of dark, lead-colored, hard slate-rocks in a nearly vertical position. Another parallel ridge, separated from this one by a ravine, is found to be composed of the same slates, which inclose some interstratified belts of quartzite. Climbing across the hill, we come into the valley of a good-sized creek flowing from the west ; we cross it, ascend on the opposite side another very steep slate-hill, and find the south-western section corner located on its summit. The slates of this last hill inclose conglomeratic seams, with water-worn granite pebbles ; they consist, like those on the other side of the creek, of a granular, quartzoso-feldspathic ground-mass, which in some more compact seams of the rock is full of pale green acicular hornblende crystals crossing each other in every direction. This large succession of slate-rocks, fully a quarter of a mile in width, without a material change in character, represents, in all probability, not one continuous series of sediments, but a repetition of the strata caused by their plication into one or several folds. We can follow these slate outcrops westward along the creek valley for nearly half a mile ; east, we find the hill over which the

south line of Sect. 22 passes composed of a slaty conglomerate, and farther east the summit is formed of fine-grained, steel-gray slates interlaminated with quartzite seams. South of this slate knob, separated from it by a ravine, a high quartzite ridge rises, extending in a continuous body westward a little distance beyond the quarter-post on the north line of Sect. 28, and after an interruption by a valley, continuing in an equally high range of quartzite hills trending across the centre part of the N.W. quarter of Sect. 28 and of the N.E. quarter of Sect. 29. The south side of these hills is lined with vertical rock-walls of quartzite, or ascends in stair-like, cliffy offsets. The quartzite beds, of very massive character and raised into a nearly vertical position, dip northward ; part of them is red, colored by iron oxide, and incloses, besides, small crystals of martite, more or less copiously disseminated ; other seams are lighter-colored whitish ; often shattered rock-seams occur, recemented into a breccia. Interlaminated with the quartzites are schistose strata, partly light-colored, novaculites and argillites, partly dark, steel-gray, hard slates of hydro-micaceous composition of silky lustre ; some of them are fine-grained homogeneous ; other seams have a bird's-eye structure by glassy quartz-grains disseminated through the mass ; their gray color is due to the abundant intermixture of minutely granular martite. These dark slaty seams occupy the lower horizon of the series, and form generally the basal part of the rock-bluffs all along the range ; frequently we see them considerably corrugated or completely shattered, and recemented into a breccia by a sandy, hydro-micaceous, schistose material. South of the high range we find a detached lower quartzite ridge in the N.E. quarter of the S.W. quarter of Sect. 28. The beds dip north under an angle of 50° or 60° ; uppermost are compact, whitish, thick-bedded quartzite layers ; the lower beds of the series are conglomeratic, and consist principally of flinty quartzite pebbles imbedded into a ferrugino-micaceous or chloritic sand-rock mass of compact quartzitic structure. The south side of this ridge is lined with low cliffs of this conglomerate, at the base of which follow, in conformable succession, dark reddish brown silico-ferruginous beds, interlaminated with flaggy seams of more or less pure granular iron-ore ; other rock-seams are banded jaspers, like those of the Negaunee hematitic mines. A narrow swamp intervenes then, and on the high ground south of it

the same iron-bearing strata come again to the surface, and compose nearly all the surface on the south side of the valley, where the Home mines, Gribben mines, and a number of others have been opened. At the Home mines and the Gribben mines we find the ore-bearing beds not directly overlaid by the conglomerate of quartzite, but a dark blackish-green chloritic schist, of obscurely brecciated structure, more visible on the bleached, weather-worn surfaces, intervenes, in a belt of 60 or 70 feet in thickness. A small knob in the swamp, about 150 steps west of the first-mentioned outcrops of the ore-formation, consists of the same brecciated chlorite schist.

The just-mentioned mines, and several others adjoining them, were abandoned, some time ago, as the ore is too siliceous. The ore-formation in these localities may amount to an aggregate thickness of 500 or 600 feet, and consists principally of thin-bedded, flaggy layers of siliceous, low-graded ores interstratified with richer seams of sub-specular flag-ore, and of jasper-banded mixed ore-beds, very similar to the jasper-banded rock of the Negaunee hematite mines. There are also white and red mottled argillitic belts similar to the so-called soapstone of the Jackson mines, interlaminated with the series, which leans in steep inclination with northern dip, on the north slope of a high granite range trending along the north line of Sects. 32, 33, and 34, from west to east.

Above the ore-bearing rock-beds, in some places the before-mentioned chloritic schist is deposited ; but most generally we find a very coarse quartzite conglomerate to be the hanging wall of the formation, which conglomerate may locally have the quality of an ordinary coarse-grained ferruginous quartzite. The foot-wall of the formation is a series of micaceo-chloritic, quartzose, or feldspathic and calcareous schists, mingled with novaculitic seams, with quartz-belts, and with irregular lenticular masses of a granular siliceous limestone. Frequently these rock-beds are found in a shattered condition, recemented into a breccia ; they seem to underlie the ore-formation conformably, and repose on the south side directly on the granite ; their thickness is in these localities not much over 250 or 300 feet. A large hill, with truncated plateau-like top occupying all the south half of Sect. 27, and detached from the granite range, is totally formed of the ore-formation ; but the numerous test-pits opened on it have never un-

covered anything better than jasper-banded mixed ores, which are on the south side of the hill naturally exposed in high bluffs ; the dip of the strata is to the north.

The largest and most valuable deposits of iron-ore are found farther west, in the south half of Sect. 29, and in the north half of Sect. 31 ; and there the relative position of the ore-bearing series to the quartzite formation is so well exhibited by natural and artificial exposures that I consider these localities as the most instructive with regard to the geological structure of this part of the country. In the north half of the S.E. quarter of Sect. 29, Town. 47, R. 26, an insular low ridge, not over 80 feet elevated above the swamp lands encircling it from all sides, is composed of the iron-ore formation conformably overlaid by thick ledges of a coarse-grained red quartzite, locally changing into a coarse conglomerate rock, composed partly of rounded water-worn pebbles, partly of angular fragments of flinty quartzite, of red-banded ferruginous jasper of novaculitic or argillitic schist and other kinds of rock. The strata dip under an angle of 60° northward. The large body of the ore-formation is formed of red jasper-banded mixed ores, entirely corresponding with the red jasper-banded mixed ore-belts of the Jackson mine or Cleveland mine ; and in these mines, various larger and smaller belts of a pure hard specular ore are found interlaminated, and are successfully mined. On the south side of the valley the slope of the high hill-range is formed of the same succession of rock-beds, which there exhibit considerable variations in character of the same ledges within a very small distance. Also the dip of the strata is locally changing from an angle of 70° to an inclination of not more than 25°. Red jasper-banded siliceous ore-beds succeed one and another in great uniformity, folded and twisted, as if once they had been in a perfectly soft, flexible condition, and amounting to a thickness of perhaps more than a thousand feet. Interlaminated with them are belts of high-graded specular ore, partly of granular structure, partly in the form of slate-ore. On this series lie, at the opening of the Cascade mine, dark iron-colored, compact quartzite beds, of a middling fine granular structure, which, a short distance farther east on the hill, are in their turn overlaid by a conglomerate rock, having partly the structure of a very coarse sandstone with a micaceo-ferruginous cement being partly formed

of an agglomeration of large pebbles and angular fragments, some of which have the size of a man's head, which are all firmly cemented together by a micaceo-chloritic sandy interstitial mass, often disseminated with granules of martite. The pebbles are glassy or flinty quartzite, jasper-banded siliceous iron-ores, novaculitic, and argillaceous slate fragments, and dioritic rocks. These conglomerates have the thickness of from 50 to 60 feet, and can be followed in one continuous sheet all the way east to the Gribben mines, whose ore differs considerably from the Cascade mine ores by its lower-graded, flaggy quality, although they represent exactly the same geological horizon. The foot-wall of the Cascade mine is not well exposed, but on the intervening space between the jasper-banded ores and the granite which forms the hill row in the south half of the N.W. quarter of Sect. 32, hydro-micaceous and novaculitic beds, in connection with dioritic and chloritic schists, are occasionally denuded. A large doleritic belt transversally intersects the ore-belt of the Cascade mine ; it is well exposed in the south part of the S.E. quarter of the S.W. quarter of Sect. 29, and again in the bluffs at the saw-mill in the S.W. corner of the N.W. quarter of Sect. 32, not 50 steps from the granitic outcrops at the large bend of the creek, which a short distance below unites with the east branch of the Escanaba River. The drift-covered plateau on the west side of the creek, which occupies the north half of Sect. 31, and is on the north side bordered by high granite hills, while along its south border, formed by the Escanaba River, the granite only comes to the surface in low knobs, is in its central part underlaid by the iron-bearing rock-series. The Palmer mine, opened in this locality, is the only mine of the Cascade range which was constantly kept in operation, while all the other mines had to suspend work ; it furnishes a good quality of granular specular ore and of slate-ore. The ore-bearing rock-belt, consisting, as in the Cascade mines, of red jasper-banded mixed lean ores, with interposed richer seams, amounts to a great thickness ; it dips north under an angle of about 45°. Next below one of the productive seams is a series of light-colored hydro-micaceous schists, interspersed with large leaflets of white mica, and in the same pit these beds and the ore-seam are transversally intersected by a doleritic dyke, part of which is in a decomposing condition, friable with the fingers into

a sand-mass ; west of the pit the continuation of the same dyke crops out in a row of cliffs in which the rock-mass is fresh and extremely hard. The hanging rock of the mines is a very coarse-grained quartzite, composed of glassy opalescent quartz-grains as large as peas, and some larger, in intermixture with red feldspar crystals, cemented by a fine scaly, micaceous, and somewhat ferruginous interstitial mass. Going from Palmer mine north-eastward, aiming for the high, conspicuous rock-bluffs in the centre of the north half of Sect. 30, we have to cross two rows of low granite hills, which are terminal spurs of the high granite hills west of there ; the low ground between these granitic rock-ridges is covered with a very coarse boulder-drift, full of large quartzite blocks of identical nature with those forming the hanging wall in the Palmer mines, and abounding in masses of float-ore of very fine specular quality, and in blocks of the red jasper-banded mixed ore. Beyond these granite hills, after passing across the creek draining Lake Palmer, we find in the centre of Sect. 30 a row of low rock-knobs in our way, formed of the same quartzite as the before-mentioned drift-boulders. The well-denuded, drift-polished rock-ledges dip under a high angle to the north, and seams of the generally very coarse-grained rock are full of larger, partly angular pebbles, of glassy or flinty quartz in different colors, of banded jaspery rocks, partly free of iron, partly formed of an alternation of specular ore-seams, with red jasper, besides fragments of chloritic schist, etc. A deep ravine on the north side of these quartzite knobs separates them from the much higher rock-ridge, which was the guiding landmark for us in our course. It faces the south with vertical walls consisting of stratified silico-ferruginous rocks of reddish brown color at the breast of the cliffs, which exhibit the same northern dip as the quartzites on the opposite side of the ravine. The more northern summit-part of the rock-walls is formed of a peculiar granite-like massive rock, intimately connected with the stratified portions of the cliffs by gradations. It is a fancifully red-spotted rock, composed of a fibrose scaly, hydro-micaceous, and sometimes chloritic ground-mass, serving as a cement for densely crowded quartz-grains, with intermixture of a granular feldspathic mass ; the red dots of the rock, at first sight taken for blood-red feldspar crystals, are actually produced by a seamy impregnation of the rock-substance in this place by

hematitic pigment. The intimate relationship of this rock with the conglomeratic quartzites of the hills south of this range is obvious ; it follows the latter in regular succession, and is in its composition perfectly analogous with the altered protogine-like quartzites, which we found in nearly all the exposures in which the quartzite formation came in contact with the granite formation. On the north side of the presently considered granitoid rock, a belt of a very coarse conglomerate rock follows in conformable superposition ; its cement is dark green, colored by intermixture of chlorite scales. On this belt reposes a large succession of dark greenish-colored quartzites, of granular arenaceous structure, composed of glassy grains of quartz cemented by a hydro-micaceo-chloritic interstitial mass ; these hard compact beds inclose sometimes distantly dispersed quartz-pebbles. Some of the rock-beds exposed in association with iron-ore seams at the Gilmore mine, and those seen in the outcrops all along the railroad for a mile west of the mine, are so similar to the last-described chloritic quartzite that hand-specimens of them, laid side by side, cannot be distinguished from each other. Examining the hills farther north in this direction, we find this quartzite rock overlaid by arenaceo-ferruginous flagstones, which represent the group above the quartzite formation. Similar chloritic quartzite beds and arenaceo-ferruginous flagstones succeed above the white compact quartzites, which form the hills in Sects. 20 and 21, north of the Cascade mines. Two miles west of the Cascade mines an outcrop of the lower beds of the quartzite formation occurs under rather peculiar circumstances, and totally isolated from the eastern exposures of this rock-series. If we follow the centre line of Sect. 26, Town. 47, R. 27, from the south quarter-post of the section to the quarter-post on the north line, we find all the surface rock to be granite until we come to the centre of the section, where, on top of a terrace-like projection of the slope of a higher range, we step at once from well-denuded characteristic granites unto a coarse-grained sub-schistose light-colored reddish and yellowish tinged quartzite, consisting of grains of vitreous quartz imbedded into a silky-shining hydro-micaceous cement-mass. These well-stratified beds of about 30 feet thickness dip under high angle northward, and are regularly succeeded by another rock-belt of 25 feet thickness, very similar in composition with the former, but dark lead-colored,