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.

PUBLISHED BY AUTHORITY OF THE LEGISLATURE OF MICHIGAN
UNDER THE DIRECTION OF THE
BOARD OF GEOLOGICAL SURVEY.

NEW YORK
JULIUS BIEN
1881

PART II.

MENOMENEE IRON REGION.

MENOMINEE IRON REGION.

GEOLOGY.

THE previous Report on the geology of the Marquette district was delivered to the Board of the Geological Survey in the fall of 1879.

After its acceptance the Board decided to defer the publication until I was ready to bring in another similar description of the Menominee iron region, which, during the past few years, has with surprising rapidity grown up into a mining-centre equalling in importance the mining district of Marquette.

I was ordered, therefore, to spend the coming summer season in examination of said region, and to be ready to report on it at the end of 1880.

The results of this examination are given in the subsequent pages.

The area which had to be examined is very large, and much of it is as yet an unbroken wilderness, accessible only by slow, tedious travel. To accomplish this examination in the given time would have been impossible for me, if it was not for the most liberal assistance I received from the inhabitants of the district, all included, from the leading business men down to the ordinary laboring man, I feel it to be my duty to express here publicly my sincerest gratitude for all the acts of kindness I received from them, which I appreciate not only in the interest of science, but also individually I am thankful for the favors disinterestedly tendered to me as their fellow-man.

To learn the local distribution of the iron-bearing rock-series in the Menominee River district, its structure, and its relative position to other rocks, was the principal object aimed at in my examination. I begin, therefore, with its description, abstaining for the present from an attempt to classify it with the subdivisions adopted for the Huronian group as it occurs in the Marquette district.

The Brien and Emmet mines, 33 miles due west of Escanaba, are the first discovered, and the most eastern mines in the district; all the interval between them and the lake shore is covered with horizontal Silurian rock-beds and with drift-deposits, and no more outcrops of the Huronian formation can be found in this eastern direction; also westward, the Silurian sandstones, and sometimes the younger calcareous strata, conceal much of the older rock-formations, frequently preventing the observation of the succession of beds, and being a great impediment for the explorer.

The mines are close to a swamp, on the south side of a chain of hills trending in west-north-west direction across the north part of Sect. 22, Town. 39, R. 28. The top part of the hills is formed of horizontal ledges of Silurian sandstones, which are to a great extent covered again with drift. The ore-bearing Huronian strata, scarcely seen in natural outcrops, are in the mining-pits uncovered to the amount of about four or five hundred feet; they dip to the south under a high angle. The most southern and consequently highest strata of this succession of beds, observable in some test-pits on the land of Mr. Saxton, in the N.W. quarter of the N. W. quarter of Sect. 23, are white and red mottled hydro-mica schists, similar to the so-called soapstone of the Jackson mines of Negaunee. These are succeeded northward by a large series of well-laminated, mostly thin-bedded siliceous and argillitic rock-ledges, all of which are more or less intensely impregnated with hematitic iron oxide and with granular martite. Interlaminated between them occur seams of iron-ore of a reddish brown color, in sub-brecciated, porous, non-stratified masses, consisting of a mixture of granular martite with amorphous red oxide of iron, frequently also in part of the hydrated oxide. These ore-seams are evidently a secondary product of lixiviation of the strata by percolating water, concentrating and purifying the ore-particles, which percolation is proved by the abundant occurrence of druse cavities in the ore lined with crystals of calcspar, and with the most brilliant crystals of iron pyrites. The given description particularly applies to the eastern part of the mining location, to the

Emmet mine; the western openings, known by the name of Brien mines, are in a somewhat lower horizon of the series, and work a different ore-seam. The ore mined there occurs also in irregular pocket-like seams; it has a dark, blackish-gray color, is quite soft, friable, and consists of minute octahedric crystals of martite. The foot-wall of the ore is formed of a thick series of dark gray, thinly-laminated, argillitic, flaggy beds, richly impregnated with martite granules, and by insensible gradations merging into the ore. Farther north succeed red-colored, hematitic, argillaceous, and siliceous strata, of which little can be seen, on account of the Silurian sand-rock ledges covering them. In test-shafts sunk through the sandstones some distance west of the Brien mines, these lower beds are found to be very rich in martite and hematitic oxide throughout, and certain seams yielded 62 per cent, of iron by analysis, but for the present no actual mining for shipment of the ore has begun in these localities.

In the pits of the Brien mine a very good occasion is offered to observe the superposition of the Silurian sandstone over the nearly vertical Huronian strata.

The lower ledges of the sand-rock constitute generally a breccia by copious intermixture with angular fragments of ore and other rocks of the ore-bearing group. Deep clefts in the Huronian strata, widening below into large cavernous spaces, are seen here replenished with sand-rock, and the curious fact happened to the miner to find the horizontal Silurian ledges below in a shaft sunk through upright Huronian beds. The Silurian sandstone is sometimes deep red-colored by hematitic pigment, but the higher beds are usually not tinged, white; it amounts on top of the hill to a thickness of at least 75 feet, and high bluffs of it occur near the north line of the west half of Sect. 22. The Silurian limestones above the sandstone formation (calciferous sand-rock) occur in outcrops on top of the hill near the quarter-post on the north line of Sect. 23, and in the test-pits opened in the N.W. quarter of Sect. 24 the same siliceous and dolomitic lime-rock is struck, which in certain seams incloses a large amount of concretionary masses of copper pyrites, by decomposition partly transformed into malachite and azurite. North of the Brien mines are, for quite a distance, no outcrops of Huronian rocks of any kind; south of them, across the swamp, the surface is likewise covered with drift-deposits, but in some test-pits opened in the S.E. quarter of Sect. 21 the hydro-micaceous white and red mottled schists, in connection with siliceous and argillaceous hematite ores, have been found. West of the Brien mines and of the exploring pits in the N.W. quarter of Sect. 22, the iron-bearing rocks are for several miles hidden from view by drift-deposits; the first outcrop we find, by following the railroad, is a dark gray slate-rock exposed on the south side of the road in the N.W. quarter of Sect. 19. From here this slate-rock is traceable into the south half of Sect. 13 of the next Town. 39, R. 29, where a wide belt of the slates, alternating with quartzose seams, is exposed in the embankment of the Sturgeon River, within sight of the railroad bridge; the strata dip south under a high angle, and strike west-north-westward. The drift-masses covering the slate-rock are full of siliceous flag-ore pieces. Examining the surrounding country northward, on the west side of the river, we find, a few hundred steps north of the railroad, a series of test-pits opened by Mr. Dike, in which clay-slates are uncovered somewhat softer than those in the river embankment, and lighter gray or bright red-colored by impregnation with iron oxide; their dip is south, conformable with the others. From the position of the test-pits we must infer a great thickness of this succession of clay-slates; farther north follows an equally large series of well-laminated siliceous and jaspery rock-beds richly impregnated with iron oxide, in the red amorphous condition, and in crystalline granular form, which latter imparts to them a dark gray color with a dull metallic lustre. Interstratified with these siliceous flaggy ledges are softer argillaceous seams, likewise rich in iron oxide; and some seams occur which almost exclusively consist of minute crystalline grains of the oxide mingled with only a small proportion of argillitic or siliceous substance. Such seams are often several feet wide, and expand sometimes into pocket-like dilatations 20 and 30 feet wide, which constitute the valuable ore-deposits of this formation. The ore of all the mines in this range has a dark, blackish-gray color, somewhat glistening from the reflex of the minute crystals which compose the porous, rather soft mass, easily crushed into a sand-like powder by the pressure of the fingers, but exceptionally harder and compact masses of the ore occur, resembling the finer-grained specular ores (the so-called steel-ore) of the Jackson mine of Negaunee.

North of Dike's mines, along the east slope of the hill-range, are a number of other test-pits, all of which exhibit similar ferrugino-siliceous and argillaceous beds, occasionally inclosing a seam of higher graded ore. The whole series of the ore-bearing strata amounts to more than a thousand feet in thickness, and retains throughout the same general character, although a great many variations in the aspect and molecular structure of the ledges occur, which to describe would be a useless task. This ore-bearing series dipping to the south is conformably succeeded on the north side by siliceous limestones in thick massive ledges, amounting to a belt of over 200 feet in thickness; they are exposed along the north slope of the hill-range which borders the south side of Pine Creek valley, and extend eastward across Sturgeon River through the north halves of Sects. 17 and 18, Town. 39, R. 28, where several parallel low ridges of the limestone project from the undulating drift-covered pine plains.

North of the limestone outcrops, on the west side of Sturgeon River, is the mouth of Pine Creek, surrounded on both sides by a broad belt of rolling hill-lands deeply covered with drift. On the east side of the Sturgeon River no natural exposures of rock are observable north of the limestone belt; but in the S.E. quarter of the S. W. quarter of Sect. 7, Town. 39, R. 28, test-pits have been opened, not more than 300 steps north of one of the ridges of limestone, in which, under a cover of from 5 to

25 feet of drift, a large series of flaggy rock-beds, richly impregnated with bright specular iron oxide granules, has been found to succeed the limestones conformably, in descending order, as both of them dip under a high angle southward. These banded, flaggy rock-ledges, consisting of an arenaceous, quartzose, and partly feldspathic ground-mass, in intermixture with various proportions of the specular oxide, amounting to from 25 to 65 per cent of the rock-substance, by their bright metallic lustre, equalling sometimes that of the specular slate-ores of the Negaunee district, and by the large average percentage of iron in all the ledges, are very tempting for the explorer; but so far all the energetic efforts of the owners of this place to find a rich marketable quality of ore have been in vain. In such explorations frequently much money is thrown away uselessly, by misconception of the nature of the ore-deposits. Many of the miners who were trained in districts where the ore-deposits are found in fissure veins, firmly adhere to the prejudice that also in this part of the country an ore-seam of inferior quality near the surface may become very rich at a greater depth, which is often the case in fissure veins; but here the ore-deposits are regular layers of oceanic sediments which - once were horizontal, and most likely consisted of the same material in all parts of such a layer within distances not too remote. These beds we find now in an upheaved, often nearly vertical position; we see cross-sections through a number of successive deposits exhibited at the surface, of which each layer may differ from the other, but the nature of every one of the layers wilt as a rule be the same in all its parts, be it near the surface or hundreds of feet below it. An explorer may therefore cross-cut a formation from one layer to the other, and reasonably expect to strike a rich ore-seam after he went through many poorer ones; but to sink down parallel with an ore-seam of inferior quality in the expectation to find it changing into a rich ore, is folly. A narrow belt of ore may increase some in width if followed to a greater depth, but it will never improve in quality below if it is poor at the surface.

How wide this belt of iron-bearing strata is, and what kind of rock-beds succeed it, is not known, as north of the test-pits all the surface is covered with drift-deposits for the distance of a quarter of a mile, where we meet with high bluffs of quartzite, which form part of a belt of quartzite ledges, amounting to not less than a thousand feet; their dip is in discordance with the iron-bearing rock-series. In the bluffs a quarter mile below the falls of Sturgeon River the quartzite dips north-east, and in some localities on the west side of the river the dip is north-west or north. The quartzite formation is, farther north, seen to repose inconformably on the granites, which form the bed of Sturgeon River at and above the falls. The granite and quartzite formations shall be considered in another place, as our present object is to examine the iron-bearing rocks of the south belt of this formation.

West of Dike's mines, located in the N. W. quarter of the N. W. quarter of Sect. 13, are the East Vulcan mines, opened along the south line of Sect. 11; another company also sunk a shaft close to them, in the N.E. corner of Sect. 14. The character of the formation is the same: an alternation of highly ferruginous, harder siliceous, and softer argillitic beds, interlaminated with various seams of iron-ore, is laid open for observation in the different mining-pits. One of these ore-seams, much wider than the others, but quite irregular in its diameter, consists of the before-described dark blackish-colored, soft, friable crystalline oxide, which is characteristic of all the mines in this range; some of the narrower seams of ore are hard, compact, and resemble the fine-grained so-called steel-ore of the Negaunee mines. The strata are so near to a vertical position that it is often hard to decide which way they dip. North of the mines extend undulating drift-covered plateau-lands, on which Silurian sand-rock is found in patches to underlie the drift; farther on, a steep descent is made into the valley of Pine Creek, through ravines washed into the drift, and near the base of the slope cliffs of the limestone formation project, showing a decidedly southern dip. South of the mines the hill-side is covered with drift, and slopes down to a swampy depression of the rolling, drift-covered plateau-lands, a broad belt of which borders the valleys of the Sturgeon and the Menominee Rivers. This plateau is underlaid by the slate-rock and quartzite beds mentioned before as being exposed in the embankment of Sturgeon River, in sight of the railroad bridge. Outcrops of them are observable near the quarter-post on the west line of Sect. 13, close to the railroad track, at which place crystalline diorites are inclosed within the ledges in apparent parallelism with them; but I consider them as intrusive. The dip of all the beds is south.

Proceeding west, we find in the N. W. quarter of Sect. 10 and in the adjoining part of Sect. 9, the Vulcan mines, occupying the south slope of a prolongation of the same range on which the East Vulcan mines are located. The ore-formation is here much better exposed than in the other places, partly by artificial denudation in the mines, partly in. natural outcrops. In the eastern pits, situated near the west line of Sect. 10, the strata are in a nearly vertical position, dipping south; in the western pits, in Sect. 9 their dip is less steep, and in places an inclination of the beds is observable, deviating from a horizontal position only 20° or 30°. The ore mined in the different pits represents different seams, but the quality is in all much alike, the soft, easily friable, so-called blue ore of the miner. In the pit intersected by the west line of Sect. 10, the ore-seam, very changeable in its width, is inclosed between hard siliceous banded rocks resembling the jasper-banded, mixed ore-beds of the Jackson mines of Negaunee, but the alternating-bands of jasper and iron-ore composing this rock are not so conspicuous, as the jasper has a dark purplish and not a bright red color like these. In the pits in Sect. 9 a large series of intensely red-colored slaty argillitic beds forms the hanging wall of the ore; these openings are north of the pits in Sect. 10, but nevertheless the strata seem to be above the others. On the higher part of the hill north of the mines, a large succession of highly-ferruginous;

siliceous, and argillitic thin-bedded or thicker banded rock-beds is exhibited in numerous test-pits. The top of the hill is covered with horizontal Silurian sand-rock, and in a test-shaft sunk there through the sand-rock, light-colored quartzites, in connection with white and red streaked hard micaceous argillites, have been brought to the surface, which seem to belong to the horizon of the limestone formation, although no calcareous rocks have been found in the shaft as far as it went. South of the mining-pits, along the slope of the range, here and there red and white blotched hydro-mica schists are exposed, similar to those found in the test-pits of Mr. Saxton, south of the ore-bearing rock-belt of the Emmet mines; the base of the slope is formed of well-stratified sandy and gravelly drift-accumulations. Lake Hanbury fills out the bottom of a depression between the ore-bearing hill-range and another row of lower hills which rise with steep rock-bluffs from the south shore of the lake.

These hills, making part of the before-mentioned belt of drift-covered plateau-lands north of the Menominee River valley and west of the Sturgeon River, are formed of a large succession of dark blackish-colored clay slates, merging into various modifications of lighter gray-colored, partly silky-shining micaceo-quartzose and feldspathic schists, which contain a considerable proportion of carbonate of lime, or of sparry carbonate of iron, and of numerous interlaminated belts of dark-colored granular quartzites, composed of brightly glassy grains of quartz in intermixture with a micaceo-schistose ground-mass, and with a ferrugino-calcareous cement, which makes the rock hard and compact; by exposure and lixiviation of the carbonates from the rock the outside becomes porous to the depth of from half an inch to an inch, and these pores are filled with brownish or orange-colored ochraceous iron oxide.

In the geological reports of Wisconsin, Major Brooks gave a lengthy description of the different ledges composing this rock-series; he suggests a plication and repetition of the strata in this broad belt of exposures, amounting to over a quarter of a mile in width, which is probably the case, as beds of the same kind repeatedly occur when we go across this succession of beds, although no synclinal and anticlinal position of the ledges is observable. On the north side of the hills the dip of the strata is clearly southward, in the centre part of the outcrops they are nearly vertical, and on the south side of the hills, which present vertical escarpments of slate rock, in places a northern dip of the strata is observed; this may, however, be merely a slight tilting over of the marginal vertical ledges, for want of support on the free side. South of these bluffs is the valley of a creek running east into Sturgeon River, which is the outlet of Lake Hanbury. Farther south, from the creek to the Menominee River, undulating drift-hills fill out this interval of something more than a mile, and no Huronian rocks are seen to come to the surface.

Returning to the iron range, we find the Curry mines in the S.W. quarter of the N.E. quarter of Sect. 9, in which a large seam, of the soft blue ore occurs under similar conditions as in the adjoining Vulcan mines. Next to it, in the S.E. quarter of the N.W. quarter of Sect. 9, are the test-pits of Mr. Stephenson, in which the siliceous flaggy strata of the iron-formation, interlaminated with narrow ore-seams of a siliceous character, have been found, but going deeper with the pits, in nearly all of them the quartzose layers of the limestone formation were struck, and the place was then abandoned. Very few steps north of the pits the limestone formation is naturally exposed, and from there a chain of knobs of limestone trends in north-west direction diagonally across the N.W. quarter of Sect. 9, connecting with the limestone outcrops in Sects. 4 and 5, which form the foot-wall of the ore-formation in the Saginaw and Norway mines. The strata dip, conformably with the iron-formation, to the south; the upper layers are quartzites rather than limestones, and have an unhomogeneous brecciated structure; below them follow limestone beds of various shades of color, whitish or reddish, and more or less intersected by siliceous seams parallel with the bedding and transversally; a large conglomeratic belt occurs in this association, composed of very unequal larger and smaller limestone fragments, of a partially angular, and in part rounded form, in intermixture with quartz fragments; the cement of the rock is calcareous. The thickness of the limestone formation in this place amounts to not less than four or five hundred feet, and is probably much larger, if an accurate measurement should be made.

The higher hills of the iron range east of Stephenson's test-pits are interrupted here by a broad, swampy depression; only the row of low limestone knobs crosses the swamp, and forms connection with the equally high range which rises on the opposite side, trending from there in the same north-west direction as the former eastern range.

On the slope of this west range are mines opened by four different companies in close proximity to each other—the Saginaw mine, in the S.W. quarter of the S.W. quarter of Sect. 4; the Stephen-son mine, in the N.W. quarter of the S.W. quarter of Sect. 4; the Norway mine, in the east half of the S.E. quarter of Sect. 5; and the Cyclops mine, in the S. W. quarter of the S. E. quarter of Sect. 5. The strata laid open in the pits of the Saginaw mine dip with great regularity to the south, under an angle of from 60° to 70°; well-laminated, thin-bedded, partly siliceous, partly argillitic beds, rich in iron oxide, inclose the ore-belt from both sides, which consists of the usual so-called blue ore. South of the pits the surface is deeply covered with drift deposits; north of them are the shafts of the Stephenson mine, which, with the exception of an abandoned open pit, is altogether underground work. The ore-belt of the Stephenson mine likewise dips under a high angle southward, and not over 50 feet north of the shaft are outcrops of the limestone formation, conformably dipping under the ore-formation. Among the waste rock hoisted from the shaft are blocks of a crystalline, half-decayed, brittle diorite, in which the feldspar crystals and the hornblende are partially transformed into an absorbent

kaolinitic mass retaining the shape of the crystals. The largest part of the waste rock is a dark-colored schist of chlorito-argillitic composition charged with granular martite; some of it has an amygdaloid structure, and in place of the amygdaloid nodules are cavities left, filled with a pulverulent ochraceous residue. West of these mines, and in direct continuity with them, is the Norway mine; it occupies the higher part of the slope, and all the work is done in open pits. The summit of the hills is formed of horizontal Silurian sandstones amounting to considerable thickness; the lower part of the Silurian strata consists of a coarse breccia of the shattered ledges of the ore-formation, recemented on the spot by the Silurian sand washed into the interstices between the fragments. These brecciated masses covering the upright strata of the ore-formation, and filling, in wedge-like accumulations, deep ravines which existed between them, are well exposed in the mining-pits. Various belts of ore occur in the mines, and the intermixture of rock-seams between the ore-masses requires often much labor to separate them from the ore. North of the ore-bearing beds a limestone belt conformably underlies them, as in the other before-mentioned mine. The upper layers of the limestone formation are almost exclusively a quartz rock of brecciated structure; farther north are purer, compact, fine-grained limestones, of red, white, and gray color, with interlaminated schistose seams of calcareo-hydro-micaceous composition, and of cherty bands. The thickness of this formation amounts to at least three or four hundred feet. North of the limestones follows a large series of light-colored red-dish, or gray or greenish slaty argillites, with interlaminated arenaceous seams, and some of them rich in mica scales; they seem to underlie the limestones conformably; but for the present I will not attempt to solve this question, and go on westward with the examination of the ore-formation.

The Cyclops mines are on the same hill as the Norway mines, but represent a higher horizon of the iron-ore formation; most of the rock-beds disclosed in the mine above and below the ore-belt are argillites, red-colored by hematitic pigment, or gray-colored by martite granules disseminated through the masses; still there is one large siliceous rock-seam, of a compact jaspery texture, and richly impregnated with ore-granules exposed along the slope, some distance east of the western pits, and south of the ore-belt. The ore of the Cyclops mine is a very soft, friable blue ore of excellent quality; the seam is unequal in its width—in places 30 feet wide. In others much narrower—and irregular in its course, as the strata inclosing it are considerably distorted by their upheaval.

The superposition of the Silurian sand-rock on the ore-formation is, in the west pit of the Cyclops mine, most beautifully exhibited; the lower beds adapt themselves to the curved surface of a trough in the Huronian strata, and in the same measure as they fill up this depression they straighten and finally become perfectly horizontal; the lower beds always inclose ore fragments and other rock pieces of the underlying formation.

West of the Cyclops mine the continuation of its ore-seam has been much hunted for, but so far without success. A great many test-pits were opened on both sides of the county road to Quinnesec, in the west part of Sect. 5 and in the east part of Sect. 6, in which the jaspery and argillitic strata of the ore-formation, with interposed seams of a hard siliceous ore of a dull metallic lustre, are found. In the test-pits opened by Mr. Curry in Sect. 6, on the higher part of the hill-slope, north of the road, strata of a lower position occur, lighter-colored than the others, and of more argillitic than siliceous character, amounting to a large succession of thinly-laminated flaggy layers, part of which contains very little ferruginous matter, but much the greater part of them is disseminated with small octahedric crystals of martite sparingly, or in proportions overbalancing the argillitic ground-mass—not enough, however, to give them value as an iron-ore in the present market. Other test-pits are on top of the hill-range, sunk through a capping of horizontal Silurian sand-rock, under which, regularly, cherty rocks and hard schistose argillitic strata of a sub-crystalline grain, and of pale whitish or reddish color, were found, which represent the upper horizon of the limestone formation.

Farther west, in Sect. 1 of the adjoining Town. 39, R. 30, many test-pits have been opened in the N.E. quarter of the section, but the drift-deposits and the underlying Silurian sandstones amount here to such a thickness that, as far as I can judge from the material thrown out of the pits, none of them was dug deep enough to reach the Huronian beds below the sandstone. Further on, in Sect. 2, nothing of the iron-formation can be discovered near the surface; but a row of limestone bluffs commences not far from the east line of the section, on the north side of the county road, and extends without interruption to the N.W. corner of the section, which is located on the limestone cliffs; south of the road are drift-covered pine-plains, with no outcrops within a mile's distance. The limestones dip to the south under an angle of about 70°. Some test-pits have been opened by Mr. Wendell about 30 or 40 steps south of the bluffs, in the N.W. quarter of the N.E. quarter of Sect. 2, in which light reddish or gray-colored fine-grained, hydro-micaceous, sub-schistose, absorbent rocks have been dug out, associated with harder sub-crystalline compact ledges, more of a feldspathic composition, but evidently only a modified molecular form of the same material. In other pits nearer to the bluff, cellulose quartzites, red-colored by iron oxide, were found.

The mentioned limestone bluffs form the south edge of a large area, having limestone as a surface-rock, which embraces the largest part of Sect. 35 and the N.E. diagonal half of Sect. 34, Town. 40, R. 30, as far as it can be ascertained by outcrops; but it is very probable that the extent of this area would be much larger if the thickness of the drift-deposits covering the surface of Sects. 27 and 28 did not prevent the observation of the older rock-beds underlying them. The creek draining Lake Fumee intersects this area, and on both sides of it are fine exposures; it forms a cascade where it runs over

the marginal ledges of the rock-belt. The thickness of this limestone formation cannot well be estimated, as it is folded into several successive synclinal and anticlinal arches, which folding is clearly exhibited in some of the low knobs projecting over the swampy ground in the S.W. quarter of Sect. 35; but commencing at the bluffs an eighth of a mile east of Quinnesec village, a measurement of the beds; so far as they succeed each other with undisturbed regularity along a wood-road which leads northward across the well-denuded strata, shows its thickness cannot be less than six or seven hundred feet. These limestones have great similarity with the Huronian limestones of the Marquette district; they are usually fine-grained, of conchoidal fracture; their color is reddish or whitish or gray; large belts of them are a breccia of sharp angular fragments of different kinds of limestone, or represent a shattered rock-mass recemented again without intermixture of foreign fragments. All of them are of dolomitic composition, and in a degree siliceous, often full of quartzose seams parallel with the stratification, or intersected transversally by an irregular network of linear cellulose veins; certain ledges of this rock-series are exclusively formed of a flinty quartz, and such are frequently in a brecciated condition, formed of fragments of various color; large blocks of this kind are quite common in the boulder-drift which covers the limestone area; very large ones lie on the road midway between Quinnesec and Lake Antoine.

The limestone bluffs abruptly terminate at the N.W. corner of Sect. 2, and disappear under the drift. Proceeding in the direction of their strike about 100 steps farther, we find, after crossing a ravine, at once exposures of the iron-bearing rock-series. We have now come to the location of the Quinnesec mines, situated in the S.E. quarter of the S.E. quarter of Sect. 34, Town. 40, R. 30. The limestone belt is, however, not interrupted here; it only recedes, and, retaining its southern dip, continues onward north of the iron-formation, which composes a conspicuous chain of hills trending from here west-north-west. The ore-bearing strata of the Quinnesec mine dip northward, while in all the previously examined localities their dip was south, conformable with the dip of the limestones.

The succession of beds composing the ore-formation at the Quinnesec mines is not less than a thousand feet thick. It consists in the southern, as it appears the lower part of the series, of compact, even-bedded flaggy or banded thicker siliceous ledges, impregnated in the various beds with larger or smaller proportions of iron oxide, particularly with granular martite of, metallic lustre; among them are seams carrying as high as 60 per cent of the oxide, which are too narrow to be used. The sedimentary lamination and cleavage of the beds are generally parallel, but some of the seams, consisting of a hard hydro-micaceo-feldspathic substance, less Impregnated with oxide, have a schistose structure, and their sedimentary lamination is oblique to the cleavage. North of this part of the series follow somewhat softer, ferruginous, argillitic, also well-laminated strata of a grayish color, in alternation with the siliceous ones. At this horizon occurs a belt of a porous, soft, well-laminated ore (the blue ore of the miners), amounting to from 10 to 20 feet; north of the ore-belt; the ferruginous flaggy layers continue for some distance, and farther off the limestones crop out, with a southern dip.

The top part of the hill is formed of Silurian sandstones, the lower beds of which are a breccia of ore-fragments. In the mining-pit the Silurian sand-rock is seen to fill out a deep excavation worn into the surface of the Huronian strata, just at the place where the productive ore-belt occurs; the undermined sand-rock ledges, left without a support, commence to break down by their own weight, and make this part of the mine very dangerous. A short distance west and north of the mining-pits an exploration was made with the diamond drill, giving the instrument an inclination to the south. The drill went first through Silurian sand-rock; then, for over 500 feet, through siliceous compact limestone strata; next, a not very thick belt of light-colored argillites was penetrated, and last, the red-colored iron-bearing rocks were struck; the entire length of the drill-hole amounted to 750 feet. South, at the base of the Quinnesec ore-range, are outcrops of gray-colored silky-shining schists in a vertical position, consisting of an interlamination of linear seams of quartz, and sometimes of granular feldspar, with a hydro-micaceous ground-mass. Farther south are drift-covered pine-plains, which terminate with steep bluffs at the Menominee River. South-east of Quinnesec, in Sect 11, these drift-bluffs are half a mile off from the Menominee River, and in various places on top and on the slope of the terrace-land, slaty and quartzose rock-seams In a vertical position are exposed, striking in a west-north-west direction. This series of rocks, which amounts to a great thickness, consists of a variety of harder quartzose seams. Some are amorphous, flinty, black, and red mottled from intermixture of hematitic and magnetic iron oxide; others are composed of granules of quartz, with glassy opaline fracture, which granules are imbedded in a schistose hydro-micaceo-chloritic ground-mass; also gray-colored, saccharoidal, fine-grained quartz-seams occur. These are interlaminated between thick belts of hydro-micaceo-chloritic and more or less ferruginous schists or slates, part of which is silky-shining, quite fissile, inclosing lenticular narrow seams of quartz, perfectly identical with the above described schists exposed at the base of the Quinnesec ore-hills; others are less fissile, much harder, more of a dull aspect, in which the quartzose and feldspathic constituents prevail over the chloritic and hydro-micaceous. These dark-colored slaty and quartzose rocks are equivalents of the quartz schist formation which composes the hills on the south side of Lake Hanbury; in fact, they are a direct continuation of this rock-belt, which first is exposed in the S.E. quarter of Sect. 13; then crosses Sturgeon River, and shows itself again at the surface near the west quarter-post of Sect. 13; then along Lake Hanbury. From there it is traceable to the N.E. quarter of Sect. 17; thence an abundance of slaty fragments of this kind mingled with the drift-masses

in Sect. 18, and in Sect. 12 of the next township, show its extension in this direction, and make the connection with the outcrops in Sect. 11 complete. In the S.E. quarter of the S.W. quarter of S. 12, T. 39, Range 30, are a few low knobs formed of a diorite-like crystalline serpentine rock, intensely charged with magnetite granules and with a smaller proportion of chrome iron. Seams composed of calcspar, of silky-shining white asbestine fibres, and of grass-green amorphous nodular masses of serpentine, occur in connection with the massive crystalline serpentinic rock. All the plateau-lands surrounding these isolated rock-bubbles are deeply covered with drift, full of the before-mentioned slate fragments, but a half mile farther south the dioritic or as some call them diabasic rocks, which form the bed-rock of the Quinnesec Falls, are extensively exposed in the hills bordering Menominee River, east of the falls. These will be specially considered in another chapter.

The ore-formation soon disappears under drift-deposits west of the Quinnesec mines, and following the line of its strike we meet with outcrops of the limestone formation, as, for instance, in a ravine in the S.E. quarter of the S.E. quarter of Sect. 33, a short distance from Dikey's farm-house. The limestone beds dip to the south, and alternate there with slaty seams of a silky lustre. From there we can follow limestone bluffs for more than a mile westward along the brow of the hills.

In Sect. 33 are, south of the limestone bluffs, drift-covered terrace-lands on which some test-pits have been opened, but the drift was found too deep to go through it without incurring a great expense. North of the bluffs the whole hill-side is riddled with test-pits. All of them went through drift-deposits of various thickness, and then struck the Silurian sand-rock. Its upper strata are generally not tinged, whitish; the lower ones are often red, colored by iron oxide; and the lowest part of the sandy sediments constitutes generally a breccia, formed of angular fragments of the different beds of the ore-formation, but particularly of rich ore-pieces; cherty quartzose fragments are often abundant in it. Calcareous rocks not rarely occur in this lower horizon of Silurian deposits, formed of an agglomeration of good-sized rhombohedric dolomite spar crystals in intermixture with an earthy, hematitic, interstitial mass. Druse-cavities in this rock are lined, with exquisitely fine crystals of the span. Beneath the ore-breccia, in nearly all the pits carried to a greater depth, the siliceous beds of the Huronian limestone formation were encountered. In some pits opened near the quarter-post, on the line between Sects. 33 and 32, large accumulations of loose fragmentary masses of rich blue ore, as it occurs in the Quinnesec mines, were found under the Silurian sandstones, which at this locality project in a row of low cliffs on the higher level above the pits, while a short distance south of and below them the limestones crop out. These loose accumulations of ore cannot be transported from any great distance, as with them large bulky masses occur, composed of a great number of successive ledges, which have kept their original parallel contiguity with each other entirely undisturbed, and in consideration of all other circumstances observable, the greatest probability exists for the suggestion that the site of the ore-belt from which these masses come is north of the pits, and not a great way off from them. Going from these test-pits northward over the undulating plateau-like summit of the hill-range, we find it covered with drift, only occasionally the horizontal Silurian sand-rock ledges become exposed. At the base of the north slope of the range, near Lake Antoine, are several test-pits opened, in which, beneath the sand-rock, reddish-colored compact limestones, dipping under a high angle northward, are observable.

If we go from the test-pits on the west line of Sect. 32 a few hundred steps farther west, and thence take a southern course, we first come across a belt of limestone with ledges dipping south in steep inclination; then succeeds another broad belt of reddish-colored and partly brecciated quartzites. It projects in high vertical bluffs along the hill-side. Descending over these cliffs we find a depression of the surface, and then ascend a rounded lower ridge composed of a large succession of siliceous flagstones richly Impregnated with martite granules, some of which constitute regular flag-ores of high percentage; they dip north, contrary to the limestone formation. An equally large succession of softer, more argillitic beds, cleaving parallel with the sedimentary striation, underlies them conformably, which, instead of the martite of metallic lustre, contain the bright red-colored form of iron oxide. Beneath them follow fine-grained hydro-mica schists, partly red, partly whitish colored, or irregularly blotched with white and red spots; they correspond with the so-called soapstone of the miner, which occurred to us first above the ore-belt of the Emmet mines, and then in the Vulcan and other mines, always in a position seemingly above the productive part of the ore-formation, while here they are lowest. South of these outcrops, and partly artificial denudations, is a narrow swamp, and the hill rising on the other side is formed of drift-deposits; but a short distance west of this place are the Keelridge mines, in which the same succession of rock-beds is exhibited, but the dip of the strata is there not so obviously northward, almost vertical. We find there the red and white blotched hydro-mica schists on the south side, succeeded by others gradually changing into gray-colored schists of a bright silky lustre, composed of an alternation of linear seams of quartz, and partially also of granular feldspar, with equally thin layers of hydro-mica of strong lustre, which is often increased by a corrugation of the substance into minute wrinkles. These schists are the same as those seen in outcrops at the base of the hills a quarter mile west of Quinnesec village, and they are the transitory link making connection with the slate-rocks on the south side of Lake Hanbury. To bring the described descending section through the ore-formation in the S. E. quarter of Sect. 31 and likewise in the Quinnesec mine, in accordance with the other previously made observations, we have to infer an overturned position of the strata, either in the one or in the other of these cases before described. The occurrence of large

accumulations of loose angular fragments of ore and of other rock-beds connected with the ore in the above-mentioned test-pits on the west line of Sect. 32, on top and north of the limestone belt with southern dip, and beneath the Silurian sandstones which form the summit part of the hill-range, suggests an exposure of the ore-belt from which these fragments come, on the north part of this hill-range. A repeated plication of the strata is to be inferred from the fact that a mile farther north, near Lake Antoine, the slope and base of this same range is formed of limestone beds dipping to the north. The ore of the Keelridge mine is more siliceous than that of the Cyclops, Norway, and Vulcan mines; it resembles the ore of the Emmet mine, both of which ores seem to occur in a higher horizon than the others. West and north of the Keelridge mine the surface is too much covered with drift to allow a special observation of the structure of the hill-range, but by test-pits opened here and there the extension of the ore-formation and the concomitant limestone formation with the range is demonstrated. In the N.E. quarter of the N.E. quarter of Sect. 31 north, far from the west end of the chain which commenced at the Quinnesec mine, is the so-called iron mountain, a spur of the higher main range consisting of a large succession of banded silico-ferruginous rocks, formed of alternating thin seams very rich in specular ore-granules which have a bright metallic lustre, and of others still disseminated with ore granules, but prevailingly quartzose; some of the seams are schistose, like the specular slate-ores of the Negaunee district. The strata are almost vertical, with scarcely perceptible dip to the north. South of this series of lean ores, as they justly may be termed, are other rather argillitic than siliceous flagstones, not so rich in ore-particles as the others, but yet averaging from 20 to 40 per cent of the oxide.

Another spur adjoins the iron mountain on the north-west side, on which the Chapin mines are located. The strata in this spur are conformable with the others, dipping northward ; they are more of an argillitic character, but rather compact, not clay-like, abundantly disseminated with comparatively large crystals of martite, and inclosed between them is a belt, 30 feet wide, of a pure, soft, porous, dark blackish colored ore, composed of glistening octahedric martite granules. North of it are again argillitic strata, but they have not been intersected much in the mine, and are not exposed at the surface. About a quarter of a mile north of the Chapin mine are large bluffs of vertical ledges of limestone, striking in the west-north-west direction of the range. In the direction of their strike are other limestone outcrops, in the swamp near the railroad track, in the centre of the S.W. quarter of Sect. 30. These continue across the road, and limestone ledges are denuded on the hill-slope near the branch road leading to the Ludington mines, in the S.E. quarter of Sect. 25, Town. 40, R. 31; on the north side of the pits of the Ludington mine the limestones and siliceous cherty layers making part of it are laid open by test-pits. Farther west, in the valley of the Menominee River, we see them in the bottom of a test-pit opened in the S.E. quarter of the S.E. quarter of Sect. 23, The ore-hill on which the Ludington Mine is located is actually a continuation of the Quinnesec ore-range, but is severed from it by a broad swampy depression. The strata are in the mine almost vertical, faintly dipping to the south; the ore is a fine quality of the soft blue ore, in a belt of about 10 feet thickness; the hanging wall of the ore is formed of gray-colored rather soft argillitic flaggy rock-beds, very rich in ore-granules; the beds forming the foot-wall are ore of a siliceous character, likewise richly impregnated with iron. Following the south line of Sect. 25 of Town. 40, R. 31, we find, not far from the quarter-post, in test-pits, red-colored sericite schists uncovered, which dip to the south. Very few steps south of the test-pits, within the limits of Sect. 36, are low rounded hillocks formed of diorite, partly of massive, partly of schistose structure, and in the superficial parts in a disintegrating, crumby condition. On the north side of the soft, red-colored sericite schists, which occupy quite a broad belt of surface, succeed harder quartzose schists, likewise deep red-colored by hematite, and north of them the briskly ascending hill-slope is composed of a very large succession of nearly vertical silico-ferruginous banded rock-beds, which correspond with the ledges exposed in the Ludington mine. The banded structure principally depends upon a more or less intense impregnation of the siliceous ground-mass, with granules of martite in the successive sedimentary laminæ of the rock; this ground-mass is not always siliceous, but is often replaced by a kaolinitic substance. The summit of the hill, which forms a very prominent landmark, is composed of horizontal Silurian sand-rock ledges amounting to over 100 feet in thickness. The lowest beds of the sand-rock are, as usual, a coarse breccia of fragments of the ore-formation, recemented by the sand-masses washed over them. The north slope of these hills and the rolling lands surrounding their base are deeply covered with drift, only in the N.E. quarter of the S.E. quarter of Sect. 24, a belt of schist, with interlaminated seams of quartzite, comes to the surface, and is also still better exposed in a cut of the railroad south of the bridge across the outlet of Lake Antoine. These schists, as far as the exposures go, about 300 feet in thickness, strike west-north-west, in conformity with the general direction of the different rock-formations composing the ore-range, and their position is upright, with no definite inclination to either side ; they are dark gray colored. One portion of the series is a fine-grained, hard clay-slate, banded with thin, closely crowded, interlaminated quartz-seams of lenticular structure, wedging out at both ends, and intimately united with the interstitial slaty seams. Another sort of the schists is composed of dark micaceous or hydro-micaceous scaly ground-mass in intermixture with minutely granular saccharoidal quartz-seams in a gneissoid manner, or filled with larger glassy grains of quartz, irregularly dispersed within the micaceous body substance. Interlaminated with these schists, which are partly much corrugated by the uplift, occur belts of light-colored granular quartzite, from 1 to 8 and 10 feet in thickness.

As no other characteristic rocks are seen in contiguity with this rock-belt, its position in the series is doubtful, but its lithological character has the nearest resemblance to the slaty rock-series on the south side of Lake Hanbury. A mile north of the railroad cut, and about 150 steps below the bridge across the Menominee River, is a broad belt of slates or schists exposed in the embankment, and in the bed of the river, amounting to more than 500 feet in thickness, which consist essentially of the same micaceous scaly ground-mass .as the schists in the railroad cut; they have a much brighter silky lustre, and the described interlaminated yearns of quartz are in them much more delicate, linear. Certain beds in the slate rock-formation of the Lake Hanbury series, in the exposures of Sect. 11, Town. 39, R. 30, near the foot of the terrace, and others in the S.W. quarter of the N.W. quarter of Sect. 29, Town. 39, R. 28, are almost identical with them. Some of the silky-shining, less fissile schists on the south side of Lake Hanbury are in substance and in aspect very similar to these schists, called in the Wisconsin Reports Phyllite, according to Wichmann's determination. The strata under consideration are in close proximity with the diorites and dioritic schists, exposed right under the bridge and above it, but they are in evident discordance with them. The dioritic schists dip to the south, the so-called phyllites dip to the north. I am fully convinced of their being a co-ordinate member of the Lake Hanbury rock-series, of which they represent the higher part, while the series exposed in the railroad cut are lower beds of the same group of strata.

North of the Menominee River, in Wisconsin, and along its course on the Michigan side up to Badwater village, diorite and dioritic schist is the exclusive surface-rock, ignoring the drift-deposits which cover a large part of the indicated area. Eastward from the railroad bridge a chain of diorite hills is traceable for a distance of six miles through the north half of Sects. 18, 17, 16, and 15, into the N. W. quarter of Sect. 14, Town. 40, R. 30. North of this chain of diorite exposures are widely spreading undulating highlands, completely covered with drift, but in all probability underlaid partly by diorite, partly by granite. South of the chain we find all along it the iron-formation, though rarely in natural outcrops, as heavy drift-masses and the Silurian sandstones cover the concerned area, but a great many exploring pits have been opened in the south part of the above-named sections, which demonstrate this fact. In test-pits opened in the south half of the S.E. quarter of Sect. 18, near Moon Lake, a large series of fine-grained sericite schists were brought to the surface. They vary in color from whitish gray to red and purple; some are harder than the others, and all have a dull satin lustre. Their dip is southward. North-east of these pits, in the S.W. quarter of Sect. 17, on the higher part of the hill-slope, are other test pits, in which a very large succession of well-laminated banded silico-ferruginous rock-beds with southern dip is uncovered. All are abundantly interspersed with martite granules, but particularly the northern lower part of the group of strata is very rich in iron oxide of a bright metallic lustre. Some of these richer beds resemble the specular slate-ore of the Negaunee mines, but no seam free enough from siliceous matter to be valued as a marketable ore was discovered in this locality. Ascending the top of the hill, we find it covered with horizontal Silurian deposits, through which a great number of test-shafts have been sunk by different parties, which uniformly had the result of meeting with a deposit of a rich soft hematite ore, mingled with hydrated grape-ore concretions, beneath a cover of from 20 to 40 feet of the Silurian sand-rock, which, as usual in its lower ledges, had the character of a breccia of ore-fragments. These hematites are, as it appears, a horizontal deposit of Silurian age, probably derived from the washing of the ocean waves over cliffs of the exposed Huronian ore-bearing rock-beds, and deposition of the iron mud particles in close proximity of them. Similar Silurian hematite deposits of great purity I have also found to occur in other localities, as, for instance, in a test-shaft of Mr. B. Brien, opened in the N. W. quarter of Sect, 22, Town. 39, R. 28, where these horizontal sediments lie right on the upright ledges of the ore-formation. Such ore-beds have of course a limited local extent, and cannot as safely be relied upon as an ore-seam interstratified with the Huronian formation, but I wonder that all the parties that opened the test-pits in Sect. 17 suspended their work in disappointment, for hematite, deposits amounted in every shaft to a sufficient thickness to be profitably mined. From the S.W. quarter of Sect. 17 the ore-formation continues without interruption diagonally across the north half of Sect. 20. Wood's mines are opened in the S.E. quarter of the N.E. quarter of Sect. 20, on the slope of a steep high hill covered with drift deposits, and formed on the summit part of Silurian sand-rock amounting to a considerable thickness. The strata dip, as in the other localities, under a high angle southward. A belt of soft blue ore, resembling the blue ore of the Vulcan or Chapin mine, from 20 to 30 feet in thickness, has for its foot-wall hard siliceous rock-beds richly interspersed with ore-granules, and for a hanging wall a series of argillitic beds in various modifications, which likewise are freely charged with martite granules and with amorphous hematitic oxide. Next to the mine, siliceous slate-ores of great lustre came out of a test-shaft, which must have a position a very few feet off from the ore-belt, but in the mine such ledges are not seen.

East of the Wood mines, in the S.W. quarter of the N. W. quarter of Sect. 21, are other test-pits on the slope of the same hill. A shaft sunk there to the depth of 80 feet struck on the bottom the siliceous, cherty beds of the limestone formation; all above them was Silurian sand-rock, constituting with its lower beds a breccia of ore-fragments, limestone, and quartz pieces. From here to the west end of Lake Fumee, which is the direction of the strike of the formation, no more outcrops occur; drift-deposits form the surface crust to a considerable depth on all this interval, but undoubtedly the iron-bearing rocks are continued in this direction, as in various spots in the line of strike a very strong attraction of the

magnetic needle is perceptible. One of such spots, on which the needle is at once reversed with its north end to the south, is in the S.W. quarter of the S.E. quarter of Sect. 21, on a road branching off from the Lake Antoine road, about 150 or 200 steps from the forking.

Near Lake Fumee, in the north half of the N.E. quarter of Sect. 27, and in the N.W. quarter of Sect. 26, extensive explorations have been made along the slope of a high ridge, the top part of which is formed of Silurian sand-rock, and above it by a thick series of dolomites, representing the calciferous sand-rock formation. In the test-pits near the edge of the swamp in Sect. 27, the strata dip under an angle of about 45° south-west; the uppermost layers are thin-bedded flags, or thicker rock-seams, light reddish-colored or mottled with white. Some have an earthy, argillitic fracture, others have compact crystalline grain. They all consist of a minutely scaly hydro-micaceous ground-mass in intimate intermixture with granular feldspar, which in the harder forms of crystalline fracture prevails over the hydro-mica, a proportion of larger whitish scales of mica Is always mingled in. Some sub-porous ledges, resembling argillite, are abundantly disseminated with glassy quartz-grains, and in all of them are octahedric crystals of martite sparingly dispersed. Certain of the harder, thin, flaggy beds are on the bedding plains covered with a coating of hydrated iron oxide in dendridic ramifications of great beauty, distantly resembling fern-leaves or fucoid branches. The lower part of the formation is composed of well-laminated, dark-colored hard quartzose rock-beds, impregnated with granular martite, which gives the richer seams a bright metallic lustre, and some of them constitute a hard, fine-grained specular ore of laminated schistose structure. These siliceous lower beds of the ore formation are succeeded by light-colored compact quartzites full of cleavage seams, causing them to break into even-bedded sub-rhomboidal small fragments. Other beds of the quartzite are more massive, or cellulose quartzites occur, full of sparry seams, which are partly sparry carbonate of iron of brownish or blackish color through the whole substance, or also white rhomboidrical dolomite spar or ordinary calcspar; usually all the three kinds of spar occur together. I consider this quartzite to be identical with the upper quartzose beds of the limestone formation, and not equivalent with the great quartzite formation exposed at the falls of Sturgeon River. Quartzites analogous with those found in the test-pits are found naturally exposed a mile south-east from there, in association with the characteristic calcareous beds of the formation. They form a row of low hillocks which diagonally intersects the south half of Sect. 25; the south-east corner of the section is located on one of these hillocks. From there across the north part of Sect. 31, in Town. 40, R. 29, no outcrops are observable, but a large, broad belt of limestones, dipping under a high angle southward. Intersects the north half of Sect. 32 from west to east, forming a ridge about three quarters of a mile long, with rock bluffs on its south side all along it. Some of the strata are quartzitic; others constitute a coarse breccia of compact granular limestone fragments of light color, cemented by a dark-gray siliceo-calcareous interstitial mass; still other ledges are a quite pure granular compact dolomite. East of this ridge is a swamp, and farther on, to the bed of Pine Creek, all the surface is deeply covered with drift. This limestone ridge, surrounded on both sides by low swampy lands, is directly north of the limestone belt which underlies the ore-formation at the Norway and Stephenson mines, a little over a mile apart from it, with a swamp valley between them. Both belts dip to the south. We must therefore either suggest a rupture of the rock-belt in the intervening space, or an intervening synclinal trough connecting the two. The same correspondence in dip exists between the limestone bluffs on the roadside near Quinnesec and the equivalent quartzose beds on the north side of Lake Fumee; but in that case we can prove by natural exposures the occurrence of a repeated plication of the rock-belt in the intervening space. Besides the locality already mentioned in which this plication of the beds is seen, there is another one handy for observation in the S. E. quarter of the N.E. quarter of Sect. 34, on the roadside to Lake Antoine, where the limestones dip northward in anticlinal position with the more southern outcrops. An anticlinal position exists also between the limestones exposed in the south slope of the Quinnesec ore-range and those on the north slope of the range dipping under the bed of Lake Antoine, and great probability exists for the occurrence of a synclinal trough of limestone in the place where the basins of Lake Antoine and of Lake Fumee are now. The identity of the ore-formation of the Quinnesec mines with the ore-bearing rock-series in the Wood mines and in the test-pits on Lake Fumee, is in any case to be considered as an established fact, by their general lithological similarity, and by the relative position which they hold to the limestone formation.

Recapitulating the so far ascertained facts, we have become acquainted with three distinct groups of rock, one succeeding the other conformably, or at least in direct superposition on the other. The most southern, seemingly uppermost, is a series of dark gray-colored slaty or schistose beds, with interlaminated quartzose belts, amounting to a thickness of perhaps over two thousand feet, which I will call the *Lake Hanbury slate group*. A second group next succeeding it consists in the upper part of light red, or whitish, or gray-colored hydro-micaceous and argillitic strata; in the lower, of siliceous beds richly impregnated with iron oxide in the amorphous hematitic condition, or in the crystalline form of martite, with metallic lustre, which lower series incloses seams almost exclusively composed of martite granules, constituting the economically valuable ore-deposits. This group I will name the *Quinnesec ore-for mation;* it amounts to a thickness of not less than one thousand feet, but locally perhaps it is much thicker. The third group is formed of a series of light-colored quartzite and limestone beds of a siliceous character, usually in part of a brecciated-structure, and also amounting to at least one thousand feet in thickness,

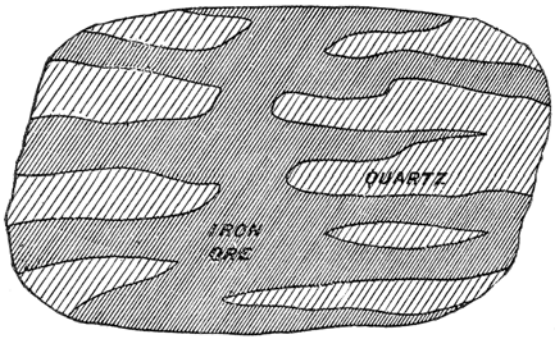
which I will call the *Norway limestone belt*. All these strata are upheaved in a certain axial direction, which is about west-north-west, and dip southward, if we consider them as a body, and overlook folds of the strata and other local irregularities. According to this, we had to take all the rock-beds which come to the surface north of the three mentioned successive rock-groups, and dip in the same southern direction, as older than they are, and all those on the south side of them as younger, if they are in a conformable position with them. As natural as this rule is in principle, as difficult it often is to determine the relative position of the rock-beds to each other, we have rarely the opportunity to see the strata in their succession without frequent interruptions, in which covered intervals, by existing plications or by a fault, the order of things may be totally changed without an indication of such a change on the surface. Moreover, the position of the strata is generally so near to the vertical that it is often arbitrary, if we decide which way we descend or ascend in the series of deposits, and if we expect to be guided by the character of the rock in decision of the relative age of the strata, we often find ourselves involved in the greatest perplexity, as the endless variety of schistose beds of lower and higher position in the stratified series is only a modified form of the same hydro-micaceous ground-mass mingled with quartz or feldspar or iron oxide, or with all of them in different proportions and in different molecular condition; schists supposed to be perfectly identical may come from horizons widely apart, with thousands of feet of sediments of another kind between them.

Inquiring what kind of rock-beds succeed on the north side of the limestone formation, we have only a few localities to resort to by which this question can be solved to satisfaction, as most universally the northern edge of the limestone formation and the underlying rocks are hidden by Silurian sandstones or by drift deposits. I have mentioned the occurrence of a large succession of siliceous specular flag-ores on the north side of a limestone belt in the S.W. quarter of Sect. 7, Town. 39, R. 28, which dip southward under the limestone, which is only about 200 steps distant from the test-pits, and likewise has a southern dip. The ore-bearing flags come on the east side of Sturgeon River, close up to its bed, but neither in the river bed nor on its west side the continuation of this ferruginous rock-belt has been discovered, although a number of test-pits have been sunk into the drift-masses which cover the surface on the west side of the river; they had to be abandoned on account of the, water before they were deep enough to meet with solid rock-ledges. Also farther west, along the valley of Pine Creek, no rocks lower than the limestone come to the surface south of the quartzite bluffs, which follow the north side of the valley at about a half mile's distance in its lower part, but farther up come close to the creek-bed.

The next locality from which information about the succession, of beds may be expected is north of the Norway mines, of which. I have likewise previously spoken, saying that a series of reddish or gray, or greenish-colored micaceo-argillitic and partly arenaceous schistose beds seem to underlie the limestones conformably, which are well exposed there in close contiguity with the ore-formation. A ditch has been dug from the engine-house of the Norway mine toward the swamp on the north side of the hill, which commences next to the limestone, and after intersection of some Silurian sand-rock beds on the surface, cuts through the above-mentioned micaceous slaty argillites crossways for the distance of over 200 steps; the same beds are also uncovered in several test-pits opened a very few steps north of the cliffs of limestone, projecting over the surface on the east side of the mine. The beds dip under a high angle to the south, as the limestones and the ore-formation do, and from one end to the other of this extensive succession no material change In the character of the beds can be perceived. Farther northward Is a broad swamp, and no outcrops or test-pits are found there, but making a circuit around the slope of the hill-side, we come, near the slaughter-house, which Is about a quarter mile direct north of the mentioned ditch, to other test-pits, in which similar micaceo-argillitic schists are dug out. Crossing there the creek, we find in the S.E. quarter of the S.E. quarter of Sect. 32 a number of test-pits, in which likewise a southern dip of the strata is observed. The most southern ledges exposed are siliceous flags, somewhat micaceous, and impregnated with martite granules In moderate quantity; associated with them are slaty argillitic beds of a greenish-drab color, harder than ordinary argillites, and of a fine-grained sub-crystalline fracture. Then follows a large belt of thick-bedded quartzose ledges, all highly ferruginous; some are regularly banded, consisting of alternating narrow seams of a pale-colored, jaspery quartz, and of a compact siliceous blackish-colored iron-ore, with a smooth flinty fracture. These beds strikingly resemble the jasper-banded ferruginous beds of the McOmber mine of Negaunee, and sometimes a broader seam of comparatively pure ore is found interstratified with jasper-banded layers. Other massive quartzose ledges are peculiarly striped and mottled by dark reddish brown or purplish seams of compact siliceous hematite, which pervade the non-tinged quartzitic ground-mass in a very irregular branching and anastomosing manner in some parallelism with the stratification; some of the seams wedge out, and others run transverse to the stratification. Most likely this peculiar distribution of the oxide in the rock-mass is the result of infiltration of the once porous sand-rock mass with iron, favored perhaps by existing cracks in the rock.

North of this quartzose iron - bearing rock-belt is a belt of graphitic schist about 8 feet wide; then follow banded micaceous quartz schists variegated with gray and red stripes, and north of them are light whitish-colored hydro-mica schists mottled with red blotches. Farther north, almost to the middle of the section, these siliceous, argillitic beds continue, and at one time again ore-bearing siliceous beds and belts of graphite are met with, which indicates a repetition of the strata, but all

seem to succeed each other uniformly, with a southern dip, as far as the exposures allow us to see. A swampy creek valley runs through the middle of the section; going across the swamp we find the above-described limestone ridge, whose ledges, as stated before, have also a southern dip. I have remarked that there must be either a synclinal trough, or a rupture of the rock-belt between the two opposite limestone ridges. The occurrence of entirely different rock-beds on the south side of the Norway limestone ridge, than we find on its north side, allows the suggestion of both cases.



Suppose we were at the Norway mines, on the apex of an anticlinal arch of the limestone formation, so compressed as to make the anticlinal sides parallel with each other, and the ore-formation to be the next incumbent younger deposits, we should necessarily expect to find on the north side of this fold, next to the limestone, the iron-formation again, which on the south side of the arch lies directly on the limestone. The micaceo-argillitic beds which we find there are very similar to the hydro-micaceous, or argillitic beds found on the south side of the ore-formation, but it is most unlikely that on the interval of 20 or 30 steps, between the two sides of the limestone crest, so sudden a change would occur, which would bring these beds in contact with the limestone and cause the elimination of the ore-bearing rockbelt a thousand feet in thickness. The similarity exists also between the beds next to the limestone belt only and those south of the ore-belt. The strata exposed farther north essentially differ. The ore-bearing rock-belt found there is unlike the Quinnesec ore-formation, and in its next proximity a seam of graphitic schist occurs, of which not a trace can be observed on the entire range from the Brien mines to the Ludington. Supposing instead of an anticlinal arch, the existence of a rupture of the limestone belt in this locality, these northern exposures had to be considered as a series of lower beds, but the reappearance of a similar limestone belt three-quarters of a mile north of them, which dips south in conformity with the others, would in this case be a circumstance difficult to explain. The hitherto described rock series of the Menominee iron range allows a much more simple and harmonious explanation of its structure if we suggest a synclinal trough of limestone in this place and revert the generally observed order in the superposition of the rock-beds, considering the most southern, apparently highest rock-beds of the Lake Hanbury series as the lowest, directly succeeding above the diorites south of the Menominee; next higher would be the iron formation and highest or youngest the limestone formation and strata north of it. This order is actually exhibited on the east side of Sturgeon River in the S.W. quarter of Sect. 7, T. 39, R. 28, also in the S.E. quarter of Sect. 32, T. 40, R. 30, and in the Chapin mine and Quinnesec mine. In all other described localities, according to this theory, which I believe to be the fact, the strata have been placed in an over-tilted position by the upheaval acting most powerfully from south to north, whereby the limestones came to lie beneath the others, and were by me at first mistaken for the oldest in the succession. North of the limestone ridge in Sect. 32 are rolling, drift-covered lands and swampy low grounds adjoining Pine Creek, on which no exposures of rock-ledges can be discovered; but crossing the creek we are very few steps off from the base of vertical walls of white compact quartzite ledges, standing in upright position; they are of great thickness. Next, north of these bluffs, the granite is seen in close, but, as it appears, discordant contact with the quartzite. If we follow the creek on its south side farther to the west up stream, we have to the left a high drift-covered hill-range: with very steep bluffs slanting down to the bed of the creek. At the place where the north line of Sect. 29 intersects it, we leave the creek and follow the section line westward to the corner, a distance of about 500 steps; here we find a number of test-pits opened, in which a large succession of slaty rock-beds in alternation with quartzite seams has been uncovered, beneath a surface crust of drift from 4 to 8 feet in thickness. The strata strike in the usual west-north-west direction, and are vertical. The slaty layers vary considerably in molecular structure, but may with propriety all be called sericite schists. Some are impalpably fine-grained; the scaly nature of their ground mass is only visible under the magnifying-glass, and the silky lustre, proper to all sericite schists, is rather dull. Others are coarser, scaly and of bright lustre; in their hardness also is a great difference—some are easily scratched with the finger-nail, others are extremely rigid and hard; the prevailing color is a dark sub-metallic gray, others are red-colored by hematite. The quartzite seams, interlaminated with the slates, are granular in structure, red-colored by iron oxide, and some of them are intimately intermingled with *hydro-micaceous*, or, what is the same, *sericitic* scales, often in addition with true mica, in hexagonal tabular crystals. The sericite schists must amount to a very great thickness, as we meet with outcrops of them over a space more than a quarter mile in width, transverse to the direction in which they strike. No iron-ore of any value has been discovered here. South-west, in the centre of Sect. 30, is a high ridge covered with strata of Silurian sand-rock over 100 feet in thickness; the lowest beds are full of ore-fragments, and on the top of the hill dolomitic sandy limestone beds overlie them. This ridge is in the line of strike with the high ridge on the north side of Lake Fumee. On its southwest side are the before-mentioned hillocks, intersecting the south half of Sect. 25, composed of quartzite and siliceous limestone. The Silurian sandstones are here found also at the base of

the hills covering the limestone, and in the lower beds very rich in ore-fragments of bright metallic lustre. Considerable work has been done in this place, opening test-pits in search of the ore-belt from which these fragments come, but so far not with the hoped for success. North of the high ridges, capped with Silurian dolomites and sandstones, the sloping interval between them and the bed of Pine Creek is covered with drift, and has no outcrops of quartzite or Huronian limestone, as it is represented on Major Brooks' map; but farther west we find some exposures of rock which are of peculiar interest, as they represent another horizon of sediments than those previously observed, likewise formed of limestone beds, different from the Norway limestone belt. In the north half of the N.E. quarter of Sect. 14, Town. 40, R. 30, near Merriman's camp, are at the base of the hills, and particularly on both sides of the creek, which flows along the north line of the section and enters there into Pine Creek, large exposures of crystalline dolomitic limestones of coarser or finer grain. Some are white, saccharoidal, like Italian marble; others are rose-colored or darker red; all copiously intermingled with silvery white mica scales. Still others are dark greenish and purple-colored by additional admixture of chlorite and of hematitic iron oxide; also quartz-seams of fine-grained saccharoidal structure often pervade the calcareous mass, and ledges occur in which the-sparry carbonates are intermingled with a large proportion of chondrodite. The sparry carbonate of iron replaces sometimes partially the dolomite and calcspar. Narrow, soft shaly seams, mostly composed of mica, argillite, and hematitic iron oxide, are at times interposed between the limestone ledges, which dip under a high angle to the south. The thickness of this limestone belt is not less than 500 feet. Above it succeeds a large belt of a reddish-colored granular quartzite 60 or 80 feet wide, which contains little cubes of iron pyrites abundantly disseminated, and certain seams of the rock-belt are composed of brown-colored sparry carbonate of iron, in cellulose intermixture with quartz. South of the quartz are again more impure micaceous and ferruginous, somewhat porous lime-rock beds with quartz-seams, inclosing concretionary masses of hard hematitic iron-ore. Farther south, but not disclosed in immediate contact with the former, follows a large series of dark lead-colored hard sericite schists, like some of those found in the test-pits at the N.W. con of Sect. 29, T. 40, R. 29. Some of the schists on the south side of the belt are black, colored by graphite. Exposures of this graphitic variety are in the N.W. quarter of the S.E. quarter of Sect. 14. The limestone belt can be traced along the north side of the before-mentioned creek into the N.E. quarter of the N.W. quarter of Sect. 14; farther on, in the N.W. quarter of the N.W. quarter, is a diorite hill which forms the terminal point of the diorite chain, extending from the twin falls of the Menominee River eastward. I have yet to mention the occurrence of large boulders in close proximity of the limestone outcrops near Merriman's camp, which consist of a magma of crystals of feldspar, quartz, black hornblende, or in its place chlorite in intermixture with rhombohedric, ferruginous dolomite spar crystals, in such an abundance as to be one of the most conspicuous constituents of the rock which, on exposure, by lixiviation of the spar, becomes full of little cavities, filled with ochraceous iron oxide. As accessory minerals in the rock occur principally magnetite, iron pyrites and copper pyrites in small, well-formed crystals. The feldspar is flesh-red orthoclase, but also anorthic feldspar seems to be present. The color of the rock is dark greenish-black, speckled with the white dolomite spar crystals of brilliant lustre. Other portions of the rock are almost destitute of hornblende and chlorite, and resemble an ordinary flesh-red granite. A boulder perfectly identical with these I found on the road-side, half a mile east of the Commonwealth mine in Wisconsin.

The eminently calcareous nature of this rock, and the abundance of boulders of large size in this locality, make me suppose a relationship between them and the limestones, but I have not been able to find an outcrop of the rock in place.

South-west of the above-mentioned graphitic schists, in the S.E. quarter of the S.W. quarter of Sect. 15, are in test-pits exposures of intensely red-colored sericite schists of soft clay slate character, and of sericitic quartzose rock-seams, containing a large percentage of granular martite, which I suppose represent the strata north of the Norway limestone belt. The whole surrounding country is so completely covered with drift, that nothing definite can be learned about the structure without resorting to the pick and shovel, or to the drill.

On several previous occasions the occurrence of a large quartzite formation north of the iron-bearing rocks and of the limestone formation, was mentioned; we have learned that north of the Norway limestone belt a large series of sericite schists of various color and hardness follows, which incloses graphitic seams, and an ore-bearing belt, which in this part of the district is not productive, but incloses, farther west, masses of pure ore in really astonishing quantities. This series of sediments is, according to my previously given views on the sequence of the strata, a younger group next succeeding the limestone. Which position the similarly situated limestones near Merriman's Camp occupy I am so far unable to determine.

Between the limestone outcrops of Merriman's Camp in Sect. 14 and the quartzite bluffs north of them, lies a valley over half a mile in width, which is deeply covered with drift-masses, extending close up to the base of the bluffs, and so we find it in all other localities along the valley of the Pine Creek, which follows for over ten miles a course strictly parallel with the trend of the quartzite formation, sometimes passing close by the high rock-walls of the quartzite, at other times a short distance off from them; but never had I the opportunity to see this quartzite in contact with any rock-beds deposited above it, except the loose drift-material. The first exposures of this large quartzite belt, in places over a thousand feet in thickness, occur in the S. W. quarter of Sect. 10, Town. 39, R. 28, which locality is something over a mile direct

north of the Brien mines; it can be traced from there in a continuous chain of exposures to the falls of the Sturgeon River, but merely the crests of the upheaved ledges project over the drift-masses, which occupy most all the surface, and nothing can be seen of other strata connected with them. On the map of Major Brooks, south of the falls, is a belt of limestone delineated, following the trend of the quartzite formation in close proximity, of which I could not see the smallest sign from one end to the other of its purported extension. At the falls of the Sturgeon River is one of the best opportunities to see the quartzite formation in its grandest display, and in its contact with the granitic rocks, found on the north side of all the length of the quartzite chain, in juxtaposition with it.

The bed-rock of the falls is granite, which evidently forms here an arched, bubble-like protrusion, dipping in all directions; the sedimentary strata above this bubble have likewise been pushed aside with the same irregularity. They have in places become entangled between the granite, and seem to dip under it, but the same ledges are seen in another place dipping in a different direction, and to lie above the granite. The granite is a granular magma of ill-defined crystals of red feldspar and quartz, in intermixture with various proportions of a black, sometimes scaly, sometimes columnar mineral, with brightly shining cleavage, of which it is doubtful to say, whether it is black hornblende, or black mica, without a microscopical examination. According to the quantity of this mineral in the composition, the granite occurs in all shades of color, from dark blackish to flesh-red. It has sometimes a banded gneissoid structure, but generally not; quite frequently it is intermingled with fine scales of sericite, and iron pyrites is also a common accessory mineral. Interstratified with the granite are belts of dark diorite-like rock, consisting of quartz, white, probably anorthic feldspar, and of a large proportion of black mica. This rock generally contains a good proportion of carbonate of lime, and often considerable quantities of cubes of iron pyrites. Some of such seams have a thinly laminated schistose structure, and are almost exclusively composed of the black mica, with only a small proportion of feldspar and quartz granules. There are other broad belts of rock, partly parallel to the granite ledges, partly intersecting them transversally, which consist of a genuine diorite formed of dark green hornblende crystals and of white anorthic feldspar. One of such diorite belts, of considerable thickness, which crosses the river a quarter mile above the falls, is in its superficial part in a state of decomposition, which allows one to crush the rock with the hand into a heap of sandy crumbs; the decomposition goes on concentrically. The rock is seen to segregate into globular masses, which easily are taken out of the surrounding crumby bed-rock, and show, when broken in two, a hard unaltered nucleus, which eccentrically becomes softer and softer. Above the falls, not far off from this dioritic transverse belt, is a doleritic dyke strongly magnetic; the exterior part of this dyke is a black aphanitic compact mass resembling basalt; the central portions of the dyke are a magma of distinct crystals of black augite and of white glassy feldspar. This is one of the very few instances in which a doleritic dyke occurred to me in the Menominee district, while such dykes are abundant in the Marquette region. In intimate, seemingly conformable contact with the granite occurs a series of schistose beds, which are exposed at the foot of the falls in an almost vertical position, but they seem to be in an anticlinal position on the two sides of the river. On the west side are stratified red-colored feldspathic rocks, crowded with granules of magnetite and with iron pyrites in small cubes; with them occur narrow seams of a rich granular magnetic ore contaminated with iron pyrites. This belt amounts to about 8 or 10 feet, and the strata dip under the granite. Next and below it is a rock-belt, 10 feet wide, of schistose, feldspathic and sericitic beds; then comes a seam of compact, finely granular red feldspar 20 feet wide, which incloses sparingly disseminated octahedrons of magnetite and little cubes of iron pyrites. Under it succeed silky-shining gray seriate schists, with a feldspathic ground-mass; then a break in the formation occurs, and the same feldspathic sericite schists dip in an opposite direction, away from the granite, and farther on in this direction we soon come to quartzite ledges, apparently incumbent on them. On the east side of the river we find similar, hard sericite schists, with interlaminated granular feldspar seams, and with several belts a coarse conglomerate rock formed of red granite pebbles and of white quartz pebbles, some of them opalescent. The cement is the schistose sericite. Some of the granular feldspathic beds of the schists are distinctly ripple-marked. Going across this schistose belt, which amounts to about one hundred feet, we come again unto granite, which seems to be in conformable contiguity with the schists. We have here evidently a series of sedimentary beds deposited on a granitic substratum, which during the upheaval became wedged in between the plastic granite mass, tilting and overlapping them locally so as to appear as the lower beds. At the base of the Sturgeon River falls is a kettle-shaped dilatation of the valley, surrounded on the east and west side by steep hill-sides formed of quartzite ledges, amounting, as I have stated before, to the thickness of at least one thousand feet; they dip under a high angle north-eastward. The ledges are thick, compact, of a finely granular saccharoidal fracture of white color, often very plainly ripple-marked. Above the falls, on the east side of the river, the quartzites are in direct but discordant contact with the granite, without the intervention of the above-described sericitic schists. The lowest beds of the quartzite are there in a degree schistose by the intermixture of linear seams of hydro-mica with the quartzite ground-mass; not all of the beds in that locality are white; some are pale reddish; also lively green-colored ledges occur there, and in several other localities west of the Sturgeon. River falls, from which an uninterrupted series of large rock-walls of quartzite can be followed across the north half of Sect. 7, and diagonally through Sects. 1 and 2 of Town. 39, R. 29; then they disappear temporarily under the drift. We

meet again with large bluffs of quartzite near the north line of the N.E. quarter of Sect. 33, Town. 40, R. 29, which we may follow along the bed of Pine Creek into the south part of Sect. 20; then comes another interruption, but high bluffs of the quartzite are again encountered in the N.E. quarter of Sect. 13, Town. 40, R. 30, which continue north-westward into the N.E. quarter of Sect. 3. On the north side of the quartzite we find all along the granite in close proximity with it, which alternates with large bulky belts of a dark blackish-green colored hornblende rock, consisting of a magma of hornblende crystals with white granules of quartz, and in part of feldspar. North from there, for miles, nothing but granite is to be seen, if the drift deposits allow any rocks to come to the surface. I made several trips across this granite area, which, in places where the granite actually forms the surface, is a very rugged country, a continued alternation of precipitous rock-ridges with intermediate swamps and windfalls. The granites are of a much more perfect crystalline structure than those at the Sturgeon River falls, and contain an abundance of bright scales of black mica. Gneiss of micaceous composition, in coarser and finer grained varieties, is very often associated with the granite, or replaces it in some localities entirely; and equally common are belts of hornblende gneiss of a black glistening aspect which occur conformably interlaminated with the granite, or with the mica gneiss of a lighter reddish-gray color.

In the north half of Sect. 12, Town. 41, R. 30, occur also belts of black mica schists in the granite, which contain regularly disseminated lenticular or globular concretionary masses of granitic composition, varying in size from that of an apple to that of a hazelnut, but in the same bed always of equal size; they are not pebbles, as they are imperfectly defined from the surrounding schistose mass. Similar strata I found subsequently farther north in various places. The dip of these granites and gneisses in the north half of the Town. Tier 41, and in the south half of Tier 42, is almost invariably to the north. In Sect. 12, near the locality in which the concretionary mica schists occur, I found a doleritic dyke dividing into many branches of an irregularly geniculated course, some of which are not more than an inch or two in width. The smaller branches consist, as it is usual, of an aphanitic black basalt-like mass; in the broader seams the rock-mass is formed of microscopically discernible crystals of black augite and of white glassy feldspar. With the exception of the before-mentioned doleritic dyke met with at the falls of Sturgeon River, this is the only one which I found in the Menominee district, as far as I went over it.

Within this area of granites we find again the Iron-bearing formation well developed in two parallel ranges, the southern of which passes through the centre of the north halves of Town. 41, Rs. 28 and 29; the northern, called the Felch Mountain range, runs along the south line of Town. 42, across Rs. 28, 29, and 30. The southern I have only transiently examined. In test-pits opened on the east line of Sect. 18, Town. 41, R. 28, at the base of the north slope of a drift-covered body of hills, filling out a large elbow of the west branch of Sturgeon River, I saw thick ledges of quartzite dipping under a high angle northward, and above them a series of micaceo-argillitic schists Intensely red-colored by hematitic pigment; work had been commenced but shortly before the time of my visit, and not much could yet be seen, as all the surface Is covered with drift.

Farther northward, in Sects. 8 and 9, a number of other test-pits have been opened. The surface Is covered with boulder drift, and under it Silurian sand-rock ledges in all the pits were first encountered; the lower part of them generally constitutes a breccia filled with iron-ore fragments of the same character, as we find them inclosed in the analogous rock-beds in the vicinity of Quinnesec. Beneath this brecciated rock silico-ferruginous flaggy strata have become uncovered, dipping under a high angle northward; they are in the superficial parts much shattered, and the limited extent of the openings does not allow to see much of the succession of beds, but the material thrown out of the pits resembles the siliceous rocks, connected with the Quinnesec ore-belt; and the narrower seams of ore associated with the siliceous beds, resemble likewise the blue ore of the Quinnesec mines, and are partly soft, friable, partly harder, approaching specular ore. North of the test-pits, in Sect. 5, is granite, the surface rock, interlaminated with large belts of gneissoid hornblende rock, dip north. In the S.E. quarter of the N. W. quarter of Sect. 33, Town. 42, R. 28, on the east side of the trail leading to Mr. Curry's test-pits on Felch Mountain, we pass a short ridge composed of granite and gneissoid hornblende rock; the strata dip north-east. About 50 steps north of the bluffs of granite, opposite to them and separated by a swampy -depression, are rock-bluffs formed of a large succession of limestone beds of white color, and of coarse-grained sparry crystalline structure. The lime-rock is full of tremolite crystals, singly dispersed through the mass, or in clusters and seams almost entirely composed of the white, silky-shining tremolite, which partly occurs in colorless, translucid columnar crystals, partly in a radiated fibrous form. The thickness of the limestone is not less than 200 feet; it dips north-west. Under the limestone are conformable beds of compact granular quartzite, with distantly dispersed crystals of green hornblende within its mass, besides crystals of magnetite and iron pyrites. Intermediate between the quartzite and the limestone are seams of dark green, well-crystallized hornblende in intermixture with crystals of diallage, which seem to be a product of metamorphosis of the hornblende, as some of the crystals exhibit the only partially completed metamorphosis. Also narrow seams of a brightly shining black mica occur in this association. The quartzite reposes directly, but inconformably, on a belt of hornblende gneiss 50 feet wide, which is in close contiguity with the granite, and runs parallel with it. North of the limestone follows another thick belt of quartzite, somewhat red-colored and in part cellulose, and this is overlaid by a very large succession of micaceous schists, composed of good-sized mica-leaves

in gneissoid intermixture with narrow seams of granular feldspar. The schists very readily decompose into a crumby mass. Above them follow harder siliceo-argillitic beds, richly impregnated with iron, in which on this hillside much test-pitting has been done, but no ore-seam of value has been discovered at this horizon. The highest part of the hill-side is formed by a large belt of a thick-bedded, compact, dark-colored quartzite about 150 feet wide, which projects in high walls along the edge of the plateau-like summit of the range. This quartzite, richly charged with martite granules, averages about 40 per cent of Iron throughout its whole bulk, and incloses narrow seams of a very rich compact ore of metallic steel color, besides concretionary, almost chemically pure oxide-masses of solid crystalline tabular form, like the ore of the island of Elba.

At the base of these bluffs of quartzite are, in several places of the hill-slope, exposures of a fine-grained glistening black hornblende rock in immediate contact with the quartzite. South of the main range, in the centre of the N.E. quarter of Sect. 32, is a smaller ridge separated from it by a swampy depression, which on the north side is intersected by an exploring trench extending from the base to the top, in which a succession of about 300 feet of flaggy siliceous beds, in alternation with argillitic seams and thicker quartzite belts, has been laid open. A great proportion of them is rich enough in granular martite to be called a lower graded ore, but no higher graded ore-seam was found. On the crest of this hill at the end of the trenches, we find the ferruginous beds, which dip to the north under a high angle, in contact with a large belt of white crystalline limestone, full of radiated fibrous tremolite crystals in some parts, in others quite pure; farther down the south slope of the hill all the surface is deeply covered with boulder-drift. On the north side of the large ferruginous quartzite belt of the main range Mr. Curry has made extensive explorations in the N. E. quarter of Sect. 32, Town. 42, R. 28. In the numerous test-pits is a great variety of quartzose and of argillitic rock-beds uncovered; most of them are richly impregnated with iron oxide, and several larger seams of a good quality of iron-ore are found interlaminated with them. An ore-belt is opened in a test-shaft about 50 feet north of the large quartzite belt, in which a soft crystalline blue ore, very similar to the Quinnesec ore, is found; farther north is a broad belt of a harder ore in a partially decomposed, hydrated condition, of ochraceous aspect on the outside; bright red-colored earthy hematite ores occur also in valuable quantities. In the north half of the N.W. quarter of Sect. 32 are other test-pits, in which about 400 feet of rock-beds are laid open in trenches, of which about one quarter represents a good salable ore; the other three quarters are to a great extent rich enough in ore-particles, to be called siliceous low-graded ore-beds, and only the smallest part consists of purely quartzose beds; the strata dip north, but are almost vertical. South of the ore-hill is a large swamp. The ore of this locality is partly a soft blue ore, like that of the Vulcan mines; partly compact and hard, but also of the dull metallic bluish color of most of the Menominee ores. North of Curry's test-pits, on the dorsal undulation on which the camp is located, the Silurian sand-rock, which forms the capping rock in most of the test-pits, is found too thick for the explorer, and nothing is known of the strata succeeding farther north. The surface slopes from Curry's camp northward into a ravine which, followed for a third of a mile eastward, brings us to a swampy valley whose north side is formed of granite hills, with well denuded rock-ledges, on which hills the quarter-post of the north line of Sect. 33 is located. We see there coarsely crystalline granite, formed of large feldspar crystals, in intermixture with white mica leaves and quartz crystals, and finer grained belts of laminated gneissoid structure repeatedly alternating with dark blackish-colored gneissoid hornblende rocks; dip northward, nearly vertical. Following the north line of Sect. 32 west, we walk over horizontal ledges of Silurian sand-rock unto the middle of Sect. 31, where, near the north quarter-post, a large belt of quartzite comes to the surface, which dips north, and on its south side we find red-colored arenaceous mica schists conformably underlying. Farther on are no more outcrops along the section line, which runs over the highest part of the hill-range, except Silurian rocks. At the base of the hills, close to the Sturgeon River, the iron-bearing Huronian beds are naturally exposed in the S.W. quarter of Sect. 31, and in the adjoining part of Sect. 36 of the next western town range, and a number of test-pits opened in these localities has much improved the opportunities for observation of this group, which there consists of a large succession of well-laminated, partly flaggy, siliceous, and in a degree feldspathic beds, copiously disseminated with granular martite of metallic lustre; also schistose micaceo-argillitic beds, impregnated with hematite and with martite, are found associated with the siliceous layers; they all clip under a high angle to the north. Some of the seams are rich enough to be used as an ore, but further explorations will have to prove whether they are large enough to be practically valuable. South of these exposures, on the other side of the Sturgeon River, all the surface rock is granite; on the north side high bluffs, tower above them composed of Silurian sandstone at the base, and on the top of dolomitic limestone beds of the calciferous sand-rock formation, which contain many but very indistinct remains of shells; these bluffs continue across the centre part of Sect. 36. North of them is a large plateau covered with the Silurian rocks, and above them with large masses of drift. After crossing the Sturgeon River in the centre of Sect. 35, we find on the south side of the valley, along the slope of the hills, outcrops of massive quartzites dipping north under a high angle. Near the S.W. corner of Sect. 26, Town. 42, R. 29, Mr. Wheeler has opened test-pits in a large series of argillitic, also harder sub-crystalline feldspathic schists, full of brightly-shining white mica scales, part of which schist, is intensely red-colored by hematite; other ledges are pale red or even white, free of iron pigment. The schists lean in a nearly vertical position on the north side of the before-mentioned quartzite belt. No iron-ore was

discovered here in any of the pits, and at present, as I suppose, the work in this place has been given up. Similar micaceous schists were observable in the before-described outcrops in Sect, 36, on the north side of Sturgeon River, where they had a position lower than the siliceous ore-bearing beds. The quartzites and micaceous schists we found exposed near the quarter-post on the north line of Sect. 31, Town, 42, R. 28, also represent an identical horizon, but in this latter locality the quartzite lies above the mica schist, in Wheeler's test-pits below it.

North of Wheeler's camp, across the river, Mr. Kempt has made explorations in the north half of the S.W. quarter of Sect. 26, and in the south half of the N. W. quarter of the same section. Ascending from the river, after leaving Wheeler's camp, over a talus of drift-masses, we first encounter bluffs of hornblende gneiss in connection with micaceous gneiss-beds in considerably corrugated condition, which rock-belt stands vertical; across it we find a swampy depression, and farther on, on the rising ground, we see in a row of test-pits over a quarter mile long, systematically dug in a transverse direction to the strike of the formation, a large succession of earthy-looking, absorbent partly schistose and well-laminated rock-beds uncovered, which, on closer examination, are found to be decomposed granites of various grain, gneisses of micaceous and of hornblendic composition, and mica schists. In all of them the original constituent minerals are yet well recognizable, but the feldspar and the hornblende have been changed more or less completely into a soft kaolinitic, minutely scaly substance; the mica resisted better the decomposing influences, but lost considerable of its lustre; the quartz is unaltered. The iron of the hornblende and in the mica is often but not always changed from the protoxide into the hematitic oxide, which imparts to these beds a resemblance with the ferruginous argillites of the iron-bearing rock-series. Some of these rocks inclose also dispersed grains of magnetite, or even a narrow seam of magnetite may occur, but from all I could observe I consider this group of decomposed granites as barren of valuable ore-deposits. The circumstance that the gneissoid rock-belt south of the weathered series is in a perfectly fresh, unaltered condition, is remarkable, as this process of decomposition has indiscriminately affected all the rocks north of it, within the distance of half a mile, and perhaps much more. An entirely similar series of decomposed granitic rocks, mica schists, and hornblende schists can be observed in other test-pits, opened by Mr. Kempt in the north half of the S.W. quarter of Sect. 14, Town. 42, R. 30; here also a wide belt, comprising many different strata, is uniformly affected by these decomposing influences; south of them are unaltered granites. The two localities are in the same line of strike with each other, which is the general direction of all the formations in this part (west-north-west), and it is probable that a continued belt of granitic rocks in this decomposed condition extends from one place to the other.

West and south of Wheeler's camp, across the central part of Sects. 34 and 33, no other rocks but Silurian sand-rock ledges can be seen at the surface. In the S.W. quarter of Sect. 32 we find again a great many test-pits opened near the so-called Wood's camp. Next south of the creek which passes below the camp are red-colored quartzose-argillitic mica schists, in which a seam of a peculiar rock is inclosed, consisting of large thick plates of white mica over half an inch in diameter, in intermixture with vitreous quartz in such a mode as to show the contemporaneous crystallization of both minerals, precluding a sedimentary agglomeration of the already formed crystals; were any feldspar present I would not hesitate to declare it a coarse-grained granite, but none is to be discovered within the mass. These mica schists dip under a high angle to the north. South of them is a belt of compact thick ledges of a light-colored reddish granular quartzite with a glassy fracture, about 120 feet wide, which incloses irregular seams wedging out or locally dilating, in which the quartzite mass is richly disseminated with middling coarse martite granules of metallic lustre; and narrower bands 6 or 10 inches wide, exclusively formed of the granular oxide, are usually associated with these quartzose, ore-bearing portions of the rock-belt. It is to be regretted that the quantity of this most excellent ore is too small to pay for its mining. South of this quartzite belt, which also contains conglomeratic ledges, follow again quartzoso-feldspathic mica schists, mingled with more or less hematitic pigment in alternation with narrower quartzite belts, which repetition of mica schists and quartz ledges continues southward for several hundred steps; then we come to other deep test shafts, from which green-colored mica schists, almost completely formed of mica leaves, have been hoisted, in association with micaceous dark-colored quartz schists, and with other coarsely granular quartzose seams, some of which consist of a mixture of quartz-granules with about an equal bulk of octahedric crystals of martite of the same size as the quartz-granules; in others of these seams the quartz-granules are in intermixture with kaolinite and with large white mica leaves. Not far south of this place the granite crops out. On the north side of Wood's camp the Silurian sandstones are very thick, and no test-pits have been sunk through them down to the Huronian beds. In the adjoining Sect. 31 still more extensive explorations are going on at present, under the auspices of different mining associations. The principal facts resulting from all these works I will condense in the following remarks: In the south half of Sect. 31, near the south line of the section, are outcrops of quartzite and of micaceous quartz schists, which are the lowest beds observable; a short distance south of them the granitic rocks occupy the surface exclusively; above them follows a large series of other rather soft mica schists, more of an argillaceous than a purely quartzose character, and generally also impregnated with hematitic iron oxide. Some are extremely fine scaly, resembling the sericite schists of the upper part of the Quinnesec ore-formation; others are formed of comparatively large

scales of white mica, mingled with the ferrugino-argillitic and siliceous ground-mass.

About in the same horizon with the mica schists occur dolomitic limestones of a reddish-drab color, with a sandy granular fracture; some beds are thick, compact, others are thin, wrinkled ledges interwoven with linear streaks of mica scales. Not far apart from them is the position of other crystalline limestones of white color, which contain an abundance of fibrous radiated crystals of tremolite; these are identical with the limestones found beneath the ore-formation at Felch Mountain. In the same part of the series occur white schistose quartzites of silvery lustre, from interlaminated linear seams of minutely scaly snow-white mica. This lower series of quartzite, mica schist, and limestone strata occupies a belt nearly a half mile in width; they all dip under a high angle northward, but the exact order in which the beds succeed each other is not so fully understood as it would be desirable. Most of our in-formation has to be obtained from the scattered pits of the explorer, and natural exposures are not only rare, but generally exhibit only a certain rock-belt for itself, and not larger sections through the beds connected with it above and below. With this lower rock-series I have yet to mention a peculiar kind of cellulose-porous rock, like burr-stone, which comes from the bottom of a test-shaft near the centre of Sect. 31, on the south side of high bluffs formed of the upper part of the ore-formation, presently to be described. The color of this rock is varying from pale whitish-red to bright brick-red, or also to a darker brownish-red. It consists of a minutely granular feldspar throughout, or the red feldspar forms a botryoidal incrustation of a skeleton of quartz-granules; the larger cellulose spaces of the rock are filled with a scaly kaolinite, or also with ferruginous matter. In the higher part of the shaft and in the neighboring pits not as deep, occur, next above this cellulose rock, rather soft, crumby arenaceo-argillitic beds, very rich in granules of specular oxide, but not enough to impart to them the quality of a high-graded ore. These beds are seen to dip under the harder silico-ferruginous ledges, which rise on their north side into a stair-like succession of bluffs, and amount to an aggregate thickness of a good many hundred feet as far as their succession is observable, the end of which we cannot see, as the top and the north slope of the hill are covered with Silurian sandstones, and with the higher calcareous ledges of the calciferous sandstone formation. This upper series of quartzose beds is throughout richly impregnated with specular ore-granules; richer seams in alternation with poorer ones give the rock the banded aspect of the mixed jaspery ore-beds of the Negaunee mines, but their color is dusky purple Instead of the bright cinnabar color of the Negaunee jasper-ores, and the siliceous ground-mass is not of a jaspery nature, but consists of granular quartz, often in intermixture with feldspathic or other aluminous accessory constituents. In the very great number of test-pits opened in this rock-belt, which is the only promising depository of valuable seams of ore in this iron range, some few seams large enough and of sufficient purity to be mined as an ore have been discovered, but generally these immense quantities of iron oxide combined with the rock-masses are not concentrated into seams of larger size, as the miner wants them, but are either uniformly dispersed through a siliceous ground-mass, not in a quantity to overbalance the siliceous matter enough, to make it harmless in the smelting process, or the really pure seams of ore are narrow, constantly alternating with low graded quartzose seams which make them unavailable for practical use. There is no particular horizon in this large succession of iron-bearing rock-beds, in which an ore-seam could be expected in preference to another; throughout the whole era in which these sediments were forming, never a lack of iron oxide existed which would have prevented the formation of an ore-belt, but the formation of such a belt depended only from a proper sifting of the heavier from the lighter molecules, induced by temporary and local conditions favoring this sifting process, which did occur at various times and in various places within restricted limits. A rich seam of ore, found in a certain position in one place, is therefore not at all a reliable proof of the occurrence of .a similar seam in a correspondent position in a continuation of this group of ledges a quarter mile off from that spot; this may be so sometimes, but just as often it will happen that we meet with a low-graded, worthless siliceous ore in the place of the rich. Geology teaches the miner where to hunt for a thing and where not, but there is another factor in such calculations, which the wisest scientist cannot foretell. Nature is no stereotype impression after a certain mould; we have to study it in every place for itself, and where our wisdom will not reach, the pick and shovel, handled by a crafty arm, often will.

Exposures of the before-mentioned limestones inclosing tremolite crystals, are found at the base of the bluffs, formed of the upper siliceous division of the ore-formation in the S.W. quarter of the N. E. quarter of Sect. 31. A belt about 60 feet wide projects there, with vertically erected ledges. Next north and south of them are argillitic mica schists of red color, and a few steps farther on the north side the banded siliceous lean ores begin to emerge. A similar limestone exposure is found a quarter mile east from this place, also on the south side of the banded lean ores. The other red-colored dolomitic limestone, intermingled with micaceous seams, occurs in the bottom of test-pits opened in the N. E. corner of the S.E. quarter of Sect. 36, Town. 42, R. 30. Going westward on the road across Sect. 36, we see on the north side a number of other test-pits opened in the banded siliceous lean-ore belt; to the left, in the south half of the S.W. quarter of Sect. 36, we see on the top of the hills large exposures of quartzite, which dips in different directions, and on its north side is a thick belt of micaceous quartz schists splitting in very even slabs, covered with large silvery mica scales on the cleavage plains. This schistose belt amounts to several hundred feet, and its beds stand vertical North of it I notice a limestone belt indicated on Major Brooks' map, but I did not go to the spot to see it. I found, however, a large

exposure of the white tremolitic limestone, near the centre of the west half of Sect. 34 and the micaceous quartz schists in contact with it. Leaving the S.W. corner of Sect. 36, and passing with the road across Sects. 2 and 3 of Town. 41, R. 30, we see on both sides large granite exposures; farther on, toward Badwater village, all the surface is covered with boulder-drift, but in a trip which I made across the centre of Sects. 17, 16, 15, 14, and 13, of that town, I found everywhere the granite to underlie .the drift-masses. In the S.E. quarter of Sect. 17 are large bluffs of quartzite near a little lake, but I have not followed them to examine their extent.

Below Badwater village are exposures of schistose and massive diorites in the bed of the river, and high bluffs of them are near the mouth of the creek entering Menominee River at the N.W. corner of Sect. 32, Town. 41, R. 30. Before we follow these exposures and others below, I will lead the reader some distance up stream, to see an interesting series of sedimentary rock-beds, whose relative position to the other strata we have become acquainted with, I have so far not been able to ascertain positively. According to Major Brooks' views, these represent the upper horizon of the Huronian group, equivalent with the staurolitic mica schists of the islands in Lake Michigamee and the next lower strata. The lithological character of the mica schists, which occur at the falls of the Michigamee River, and also near the mouth of Brule River at its union with Paint River, is indeed very similar to the mica schists in Michigamee Lake; but I leave this question open until I have had a chance to examine this group of rocks, and their connection with other rocks in the Menominee region more carefully, than by mere reconnoitring, as, for lack of time, I had to do this first time I saw them.

Rowing up the river from Badwater, we find the first rock-exposures near its intersection by the west line of Sect. 30, a short distance north of the quarter-post; in the bed of the river and in the embankment of both sides the strike of the strata is north-north-west, their dip under a high angle west and correspondingly south. Lowest are greenish-gray colored schists composed of a gritty ground-mass of feldspar and quartz granules in intermixture with sericite, which gives it a silky lustre. Next above follows a large belt of a compact rock, cleaving in very even-faced rhomboidal blocks, partly of reddish, partly of greenish-gray color, with a gritty granular fracture. It consists of a quartzoso-feldspathic sub-crystalline mass, intimately mingled with glistening, very minute scales of sericite, or also perhaps chlorite in the greenish-colored ledges. Above this belt follow again sericite schists of dark gray color, some soft, very fissile, and much corrugated into larger plications, and also into very minute parallel wrinkles, visible on the glistening cleavage plains of the schists; others of the strata are harder and less fissile by the larger proportion of quartzose and feldspathic substance in their composition; some of the beds are also richly impregnated with hematitic pigment. These last-described beds are exposed on the Wisconsin side of the river. Farther up are for a while few exposures on the river, but the compact quartzoso-feldspathic rock-ledges are in several places seen to crop out farther back on the hill-sides of the Michigan shore. In the S.E. quarter of the S.E. quarter of Sect. 23, near the east line of the section, a large dioritic, or may be diabasic belt projects in cliffs at the water's edge; it is a dark black rock, consisting of black hornblende crystals and of white semi-translucid feldspar crystals plainly discernible with the naked eyes. On the opposite Wisconsin shore are other outcrops of black, compact rocks of granular structure, composed of white quartz granules in intermixture with a very large proportion of black magnetite crystals, which compose at least half the bulk of the material. The compass needle is strongly attracted by it.

A short distance above, on the Michigan side, and on the group of islands in the north half of the S.E. quarter of Sect. 23, are again large exposures of. the compact quartzoso-feldspathic rocks and sericitic schistose layers identical with those first encountered near the west line of Sect. 30; they strike north-west, and dip southward. Farther on, in the S.W. quarter of the N.E. quarter of this same section, are large bluffs of an equivalent but coarser-grained rock, which shows more plainly than the others its origin from a sedimentary sand-rock; it has a glistening glassy fracture, on which large quartz-grains of an opaline milky hue are discernible among others perfectly translucid. Other high cliffs of the same kind of rock, associated with seams of schistose structure from intermingled sericite, occur on the Michigan side in the N.E. quarter of the N.E. quarter of Sect. 22; they strike east and west, dip south. After passing from here a bend of the river, we find a short distance off other large exposures on the Wisconsin side, which differ considerably in aspect from the former, but essentially consist of the same feldspathic quartzose granular ground-mass in intermixture with much sericite, which gives to all the beds a schistose structure, but the principal difference consists in a large proportion of sparry carbonate of lime combined with the rock substance, and also in separate seams of saccharoidal grain. These schists exhibit a much distorted, corrugated, on a shattered condition; they are hard, not fissile, and resemble certain schists found in connection with the dioritic rock-group near the upper Quinnesec falls.

Higher up, on the Wisconsin side, in the N.E. quarter of the N.W. quarter of Sect. 22 (according to the Michigan town subdivision), are very compact massive rocks of a greenish-gray color, and a minutely crystalline grain, which I consider to be diorite, as small hornblende crystals are plainly discernible constituents of the rock-mass, which, like the other beds of the mica schist series, contains sericitic or micaceous scales intermingled.

Onward comes another group of islands, and from there up to the falls of the Michigamee River are, on both sides of the river, continued exposures of the mica schist formation, with inclosed large belts of the harder

quartzoso-feldspathic and micaceous compact rocks. The strike of the formation north of the islands is east-north-east, dip south; the same strike and dip of the strata is observed at the falls of the Michigamee. It would be a useless repetition to give a special description of the rocks at the falls of the Michigamee, or of those above the islands near the quarter-post, between Sects. 15 and 16. They agree perfectly with the before-described equivalent beds first seen on the west line of Sect. 30, Town. 41, R. 30, but are much more extensively exposed, and the micaceous schists are more even-bedded, richer in mica, and consequently have a much brighter silvery lustre than in the more southern exposures. Entirely similar rocks as those at the Michigamee Falls are found near the mouth of Brule River, at which locality the immense thickness of the formation can be observed by climbing from the river-bed across the strata up to the top of the hills. The strata dip under a high angle to the south, toward the hills on the other side of the Brule, which on their south side consist of diorite; the north slope of them I have not examined.

From the falls of Michigamee River I followed the Menominee River farther on upward, which bends from here south-west. About 200 steps west of the fork of the two rivers commences, on the Michigan side, a long series of exposures of schistose beds, differing from the mica schists at the falls, and evidently representing another horizon of the same group of sediments, as a considerable similarity exists in the nature of the rock-material; but as in. this locality the strike and dip of the strata changes so very often, and frequent interruptions in the exposures occur, it is hard to determine the order in the succession of the beds, without making more detailed examinations of the surrounding country, than, I had the time to do. The strata at the falls strike west-south-west and dip south; the strata in the exposures a few hundred steps west of the forking of the rivers strike west-north-west, and dip north; and soon after we find the strata to dip south, retaining the same direction in strike with the others; subsequently we find, at the first rapids we meet, the strike of the strata to be north, and the dip in some places west, in others east. The schists are associated with massive dioritic rocks, which come to the surface in various places, evidently from beneath the schists. The schists themselves vary considerably; a part of them is fine-grained, quite fissile, even-bedded, or corrugated, silky-shining, of lighter or darker gray or greenish-gray color, and consists of a homogeneous finely granular feldspathic and quartzose ground-mass, intimately mingled with the impalpably fine-sericitic or micaceous scales. Other schistose beds connected with the sericitic are harder, less fissile, and less homogeneous, usually darker greenish colored and of little lustre; the sericite is in them replaced by a coarser scaly dark green mica, and in part sometimes by chloritic scales ; also the feldspathic and quartzose ground-mass is coarser grained, or forms separate lenticular seams, interlaminated with the micaceous. Some of them are disseminated with crystals of carbonate of lime, or calcareous seams are interlaminated, and other portions of the schistose layers are found impregnated with hematitic iron oxide. The diorites in these exposures are dark blackish-colored, sufficiently coarse-grained to distinguish the component minerals, of which the dark fibrous hornblende prevails considerably over the feldspar. All contain also a small proportion of carbonate of lime, besides micaceous scales, and an intermixture of granular quartz is often observable. I went as far as to the centre line of Sect. 17, where both sides of the river are bordered with dioritic rocks, and then returned, seeing that I had to make good many further researches before I would attempt to express a positive opinion regarding the relative age of this group of rocks. Major Brooks asserts the identity of these mica schists and quartzose-feldspathic gneissoid rocks with the staurolitic mica schists of Michigamee Lake. As the next lower strata, younger yet than the Lake Hanbury slates and the Quinnesec iron-formation, which, as we learn from his report, are placed above the Norway limestone belt, he considers the dioritic rocks exposed at the Twin falls, at the Quinnesec falls, and lower down the Menominee River, giving as his reason the parallelism of the dioritic rock-belt with the ore-formation, which dips to the south in conformity with the diorite on its south side. For the same conformity in dip, Major Brooks declares the granites and gneisses north of the Felch Mountain ore-range as younger than the ore-formation, which like them dips northward; but their superposition on the ore-formation is nowhere observable; on the contrary, the south side of the ore-range exhibits in several places the direct superposition of the ore-formation on the granite. This fact is known to Major Brooks, but he solves the dilemma by identifying the granites on the south side of the Felch Mountain ore-formation with the Laurentian; those on the north side, he claims, represent the youngest Huronian rocks. How he could do so I cannot conceive, as the concerned granitic and gneissoid rocks north and south of the ore-formation are so absolutely identical, that no one who ever sees them can doubt for a moment the equality in the age of these rocks. Moreover, this identification of the northern granite with the upper Huronian, and of the southern with the Laurentian, implies another abnormity; groups of rocks, usually separated from each other by thousands of feet of intervening strata, are in this case thought to be in immediate superposition, which does sometimes occur, but not in coincidence with another improbability like the one stated in this instance.

Examining the relative position of the dioritic rock-series to the iron-formation in the southern part of the district, we find these two groups rarely in contact, and then usually so incompletely exposed as not to allow the positive observation of their stratigraphical relations. The diorite belt exposed at the Twin falls, which has as far as ascertainable a southern dip, extends without interruption for six miles eastward from the river, and on the south, side of this belt we can observe all along the iron-formation, likewise with a southern dip. The contact of the formations is not seen, on account of the

deposition of Silurian sandstone ledges and of heavy drift-masses over the surface.

Following the western extension of this diorite belt into Wisconsin, we find it there, in the centre of Sect. 8, Town. 39, R. 19, in direct contiguity with the ore-formation of the Commonwealth mines, which, as above stated, has its position above the Quinnesec ore-formation; but in this instance also of well-exposed contact nothing definite can be made out, as the strata adjoin in a vertical position. South of the Ludington mines I mentioned on a previous occasion the occurrence of sericite schists, belonging to the lower horizon of the ore-bearing formation which dip to the south, and near by, south of them, in the N.W. corner of the N.E. quarter of Sect. 36, Town. 40, R. 31, we find low hillocks of diorite, but there also nothing can be proved; the dioritic rocks generally play the part of an intrusive rock with regard to the strictly sedimentary rock-beds of the Huronian series. A superposition of the diorite formation on the Lake Hanbury rock-series, which adjoins it the whole length of the Menominee valley from the upper Quinnesec falls to the Sturgeon falls, asserted by Major Brooks, is not observable; the nearly vertical strata of both formations are even never seen in contact. There is always quite a large covered interval between them. The nearest exposures of the two groups are observable in Sect, 26, Town. 39, R. 29, where, in the centre of the section, a hill is formed of the vertical ledges of ferrugino-siliceous flagstones and slaty beds representing the Lake Hanbury series, and about two or three hundred steps from these exposures we find, on the south side of the road to Menominee, small hillocks of diorite. Major Brooks has identified these slates with the iron-formation of the Commonwealth mine, but I see no justifiable reason to do so. The Commonwealth ore-formation, wherever it occurs, is invariably connected with graphitic schists, of which in the Lake Hanbury series none are found. Giving a description of a cross-section from the Norway mines northward, I have previously stated the occurrence of graphitic schists, in association with iron-ore seams beneath the limestone formation, but according to my theory actually above it, which position I assign also to the Commonwealth ore-formation, on the strength of its lithological similarity with the rock-series north of the Norway mines; the limestones are rarely seen in that district. Still there are on Brule River, south-west of Chicagon Lake, large bluffs of limestone to be seen in close connection with exposures of this ore-formation, and evidently beneath it.

My reasons for holding the dioritic rocks south of the iron-formation as older than the latter, are based on the lithological similarity of this formation with the dioritic group of the Marquette district, and on the degree of metamorphism exhibited by the two groups, the dioritic and the iron-bearing. In the great succession of strata commencing with the Hanbury slate group and upward, we rarely find a bed so much altered that its sedimentary structure is altogether obsolesced, and the majority of the strata shows it very plain, while in the dioritic rocks, considered to be the younger, a stratified structure is also recognizable, but not one of these thousands of feet of ledges exhibits its original sedimentary lamination with any degree of distinctness like the others; they have evidently been transformed under cooperation of heat, and partially brought into a plastic condition, which is shown by the extreme corrugation and mode of intermixture of these rock-masses, of which effects the other rock-groups do not exhibit near as high a degree. It would be very strange, then, if the lowest beds, nearest to the focus of the central heat, should have been so much less affected by these altering influences, than those pretended to be the higher upper strata of the rock crust. One might object: If the diorites are the older beds, why don't we find them just as well developed on the north side of the upheaved beds, between the quartzite and the granite? The sandy and conglomeratic nature of many of the strata of the quartzite and iron formation proves them to be shore deposits, while the dioritic group consists only of the finer material of deep-sea deposits, which explains the point in question. Moreover, the dioritic rocks are not altogether missing on the north side of the ore-formation, as we can see by the occurrence of the six-mile-long chain of diorite extending eastward from the Twin falls. A similar discrepancy between the rocks underlying the ore-formation on the two opposite sides of its exposure, is seen in the Negaunee district. On the south margin, at the Cascade and Palmer mines, it rests directly on the granite, while on the northern exposures the diorite underlies it in great thickness.

The equal dip of the strata to the south in these adjoining for-illations is not necessarily a proof of the younger age of the most southern beds. The whole succession is so near to a vertical position that in many instances it has to be left uncertain which way they dip, but suppose their dip is conformably to the south; the upheaval of the diorites by the eruption of the still more southern granite masses pushing the whole incumbent rock-series north, until all tipped over, is the hypothesis by which I explain the order in the succession of beds as an inverted one, the seemingly lowest beds being actually the youngest. But let us go and see these rocks from place to place, instead of making general speculations. The large body of dioritic rocks exposed in the Menominee River and its embankments below Badwater village, and continued to the upper and lower Twin falls and to the four-foot falls near the railroad bridge across the Menominee, have all one common character; they are dark greenish-gray or blackish-colored, partly schistose, and even slaty, partly massive, coarser or finer grained crystalline rocks, consisting all of a feldspathic ground-mass in intermixture with a dark green mineral, recognizable in the coarser grained rocks of crystalline structure, as hornblende, and in addition to it, with a minutely scaly mineral considered to be chlorite, but often nearer to mica or hydro-mica. By differences in the proportions and in the molecular condition of these three components, a great variety in the aspect of these rocks is caused.

The micaceo-chloritic constituents are more abundant in the schistose strata, than in the crystalline massive form of the rock, which is generally middling fine-grained, not much differing from the diorites of the Marquette district. The hornblende crystals are somewhat fibrous, of bright lustre; they overbalance in quantity the white feldspathic ground-mass most generally, wherefore the rock has so dark a color; still pale green beds of finer grain also occur in which the feldspar considerably prevails over the hornblendes. Iron pyrites granules are constantly found dispersed through the mass; less common is the intermixture of magnetite granules.

Among the rock ledges exposed at the lower Twin falls I observe a thick belt of an aphanitic compact rock with flinty fracture, which consists of a pale green amorphous feldspathic ground-mass, semi-transparent in thin splinters, impregnated with an abundance of very minute chloritic or hydro-micaceous scales, so distributed in layers as to give the rock on cross fractures a most minutely lineated structure, parallel with the bedding; by cleavage cracks the rock divides into rhomboidal blocks with very even surfaces. The dip of the strata at the lower Twin falls is to the south, but in places the position of the beds is vertical; at the upper Twin falls the dip is northward, also nearly vertical. At the upper Quinnesec falls the dip of the strata is southward, in correspondence with the west-north-west trend of the formation, and approaching a vertical position. In the most northern exposures on the Michigan side, below the falls, are dark green-colored, partly schistose, partly massive crystalline rocks, not differing from the dioritic rocks of the Twin falls or the four-foot falls; north of them are drift-covered terraces which extend for over a mile northward to the foot of the Quinnesec ore-range. On their south side follows a large series of much lighter-colored, grayish-green, in certain seams porphyritic schists, inclosing well-formed orthoclas crystals within their mass; they are composed of a granular feldspathic body-substance in intermixture with an abundance of hydro-micaceous (paragonitic) scaly seams, and with a considerable proportion of carbonate of lime ; also dimly defined pale green hornblende crystals are intermingled. A part of these ledges occurs in more even-bedded flaggy layers, which are the ones exhibiting the porphyritic character most distinctly.

Other beds, generally much corrugated, consist of an irregular wedge-like intermixture and alternation of micaceo-feldspathic seams and sparry laminæ; still others are obscurely schistose, hard bulky rock-masses of the same micaceo-feldspathic and calcareous composition, in which large milk-white, ill-defined sub-globular concretions of feldspar are dispersed, which make them resemble a conglomeratic rock, and certain beds are crowded with poorly defined light green hornblende crystals. Next to them follows, on the south side, a belt about 100 feet wide, of very well stratified thinly laminated rocks of silky lustre ; some are gray, much corrugated, and consist of greenish-white semi-translucid laminæ of feldspar composition of one or two millimetres' thickness, in alternation with equally thin seams of hydro-mica. Here and there are quartz-grains as big as a lentil or pea wedged in between the laminæ; they have no crystal facets, are rounded on the surface, and coated over with hydro-mica. Another series of beds intimately connected with them has a pale red color, consists of the same alternation of laminæ of feldspar and hydro-mica, but the feldspar is orthoclas; the intermixture of quartz-grains is in them more abundant than in the former, and in the micaceous part of the laminæ are numerous clusters of fine needles of black turmaline; also larger red feldspar crystals are sometimes observable. Another modification of the same schistose rock-belt is harder, less fissile, still consisting of a succession of thin laminæ with large quartz-grains wedged in between them; their color is dark gray, variegated with red ill-defined blotches, which mainly are formed of granular red orthoclase. We are now right under the falls. A large massive belt of diorite, on the south side of the before-described schists, crosses here the river-bed; it is not a single thick belt, but a succession of belts with interlaminated schistose seams, similar to the sparry calcareous schists below the falls. The massive diorite has, as I stated before, the same composition as the schists; the larger portion of the rock is a magma of ill-defined granular crystals of white feldspar, with pale green hornblende crystals, and always with some proportion of the micaceous scales and of calcspar intermingled. Its color is light greenish-gray, of a dull non-reflecting granular aspect; other portions of the rock are formed of well-defined crystals, with brightly glistening facets. If the feldspar prevails the diorite is white, dotted with green; if the hornblende prevails the ground color is green, speckled with white. These *diorites* are, in the Wisconsin Reports, described under the name of *diabase*, as by microscopical examination of some hand-specimens the discovery was made that augite besides hornblende was one of their constituents, in combination with anorthic feldspar. A number of Diorites from the Marquette region are also on the same ground pronounced to be Diabases. This is true with the specimen described by M. A. Wichmann from the Washington mine, but it is an essentially different rock from the other diabases he describes. We meet in the Marquette district with many dykes of augitic rock, some with large crystals of augite readily discernible with the naked eyes; they are, however, of a much later origin than the dioritic rocks of that region. I have not made a microscopical examination of the dioritic rocks of the Menominee region, but I was able to find in almost every exposure of this kind of rocks, specimens of a crystalline grain coarse enough to see with the naked eyes, or with an ordinary magnifying-glass, the component minerals, and in every instance I could fully convince myself of the presence of hornblende in these so-called diabases as one of the main constituents, by the bright cleavages of the crystals intersecting each other under an angle of 124°; and only in a few instances, in rock-masses which were in a state of beginning decomposition, I could observe a secondary transformation of former bright hornblende crystals, into opaque crystalline masses, which cleft by

crushing them into nearly cubical little fragments supposed to be augite.

The beds of diorite and interstratified dioritic and calcareous schists exposed at the upper Quinnesec falls in uninterrupted continuity of succession, amount, with exclusion of the beds below the falls, to about 700 feet. After a short interruption of the outcrops, we find, higher up in the river-bed, the succession of strata continued by other schistose beds, scarcely differing from the former, and inclosing from time to time belts of compact crystalline diorite. One of these belts of diorite, cropping out at the base of the rapids a half mile above the falls, is the most beautiful variety of this rock I have seen ; it consists of brightly pale green, quite large hornblende crystals, imbedded within a granular milky-white interstitial ground-mass of feldspar. The rapids in this place are occasioned by a succession of about 400 feet of thinly laminated schists, quite variant in molecular structure, but not so much in general composition. Some of the beds are smooth-bedded, very-fissile mica schists, of dark greenish-gray color, with great lustre; other micaceous strata are not fissile, unhomogeneous, curly masses, formed of an aggregation of nodular rounded crystals of white feldspar of orthoclase and of quartz, imbedded within a schistose ground-mass composed of bright blackish mica scales and of sparry carbonate of lime. Another variety of the schists, formed of micaceo-feldspathic thin laminæ, resembles a conglomeratic rock from lenticular masses of quartz abundantly wedged in between the laminæ; other similar micaceous seams regularly alternate with narrow bands of granular quartz. Also dark green chlorito-micaceous belts occur in this succession, which by gradations merge into a crystalline chloritic hornblende rock.

Beyond the rapids I did not examine the rocks of the exposures found some distance above. This whole large series of rock-beds, exposed at the upper Quinnesec falls, evidently represents one inseparable group of altered sedimentary deposits formed from bottom to top of the same material, in different molecular form and different proportion in the intermixture of the component mineral substances. This composition and structure also agrees with the dioritic rock-series of the Marquette district, as near as it can be expected in places remote from each other, which similarity is for me a strong inducement to consider them as analogous and contemporaneous formations. In the hills south of the falls, a quarter mile from the river-bed, the dioritic group is exposed in a row of vertical walls and in single cliffs; one of these localities exhibits the intersection of the massive crystalline diorite by a granitic dyke. This granite consists of a minutely granular, almost flinty ground-mass of feldspar composition, in which dimly defined large red crystals of feldspar and of quartz have segregated, besides scantily disseminated linear interrupted seams of dark micaceous scales. The larger outcrops of granite indicated on the map of Major Brooks I failed to find, in the hurried way I went over the drift-covered surface of this broken country. The rock-series at the lower Quinnesec falls is a direct continuation of the rocks at the upper falls. North and above the falls are dark green diorites and dioritic schists, as on the north side of the Menominee below the upper falls, and the same as at the Twin falls. The lighter white and greenish speckled diorites, interstratified with schists of micaceo-feldspathic composition in intermixture with a large proportion of sparry carbonate of lime, are exposed at the falls, several belts of the crystalline rock above, and another large one at the foot of them. The schists occur in a good many variations, as at the other exposures. From the lower Quinnesec falls down to the sandy portage rapids in the N.E. quarter of Sect. 24, Town. 39, R. 30, an uninterrupted row of high rock-walls forms the brow of the hills on the Michigan side, which are composed of the same, partly schistose, partly crystalline massive dioritic beds; large exposures are also half a mile north of the river in the knobs projecting over the drift-covered terrace-lands in the central part of Sect. 14. At the upper end of *sandy portage rapids* commence exposures of hard, thinly laminated micaceo-feldspathic schists like those at the foot of the upper Quinnesec falls, but of a darker greenish color; dispersed through the substance are nodular masses and streaky seams of red orthoclas. Farther on, the schists change somewhat in structure, but not materially in quality; they are in a vertical position; several belts of massive rather dark green colored and comparatively fine-grained diorite are interstratified between. them. The schists amount to 400 or 500 feet in thickness. By following the river downward we find, south of the former, much lighter whitish, or reddish gray-colored delicately laminated micaceo-feldspathic schists of a sub-porous absorbent nature, and of gritty instead of lubricous feel; portions of this schistose series of beds are in a state of decomposition, and disintegrate into loose argillitic sand-masses, or into small splintery fragments. These light-colored schists extend across the river to the Wisconsin side, which side I have not farther examined. The same kind of schist is observable lower down the river, at Devil's Gut. From there are, for some time, no more outcrops to be seen on the Michigan side of the river, until we have passed the mouth of the Sturgeon River. A few hundred steps below it a belt of serpentine about 50 feet wide, associated with asbestine and sparry seams, crosses the river obliquely; lower down, after short interruption of the exposures, another belt of serpentine, about 100 feet wide, is visible in the bed of the river, but only at low water these beds are accessible. They consist of a dark greenish black serpentine, trans-lucid in thin splinters, with a green color; it contains magnetite granules in considerable quantity, and gives with the blowpipe reaction of chrome. Nothing definite can be seen in these two exposures, in which relation the serpentine is to the dioritic rock-group, which forms the hills on the Wisconsin side at that place; but farther down, above Sturgeon falls, if we follow a small creek which enters the river not far from the quarter-post on the west line of Sect. 26, we come to the base of bald rock-knobs, consisting of a fine-grained diorite, speckled with large and small white dots of nodular segregations of feldspar

within the grayish-green dioritic ground-mass, which massive rock-belt is intersected by a dyke of serpentine about 40 feet in diameter, sharply defined from the diorite, and plainly exhibiting its intrusive nature; it strikes from north-west to south-east, about parallel with the large diorite belt of the falls, which is about 300 steps south of the serpentine dyke. The serpentine is dark blackish green, full of cleavage cracks, causing it to break into very irregular sharp-edged fragments; the surface of these fractured faces is generally covered with a thin cuticle of silky-shining asbestine fibres; other portions of the serpentine are intersected by a great many sub-parallel and sometimes anastomosing seams of chrysotil of bright satin lustre. The Sturgeon falls are occasioned by the same rock barrier, which is broken through by the Menominee River at the upper and lower Quinnesec falls. The rocks of all the three falls are perfectly similar. We find here again the light-colored white and greenish-gray speckled diorite of a more or less perfect crystalline structure, massive or schistose, and then pervaded in all directions with narrow seams of calcspar; sometimes also veins of white dolomite-spar, a foot or more in width, occur. Near the base of the falls a broad belt of thinly laminated, silky-shining hydro-micaceo-feldspathic schists, like those at the two other falls, is exposed, succeeded on the south side by another diorite belt; all the beds dip south-west under a high angle. East and south-east of the falls, the country bordering the river is extremely broken, full of large exposures which represent this dioritic rock-formation, showing its very great thickness and a great variation in the structure of the rocks, although nearly all are composed of the same constituents in different proportions and different molecular form. The order in which the various beds succeed is not clearly observable, but it appears the dark green, fine-grained diorite, speckled with comparatively large white crystals of feldspar, distantly dispersed, and quite obvious from a distance, which incloses the serpentine dyke, is one of the lowest of the exposed strata. To about the same horizon belongs the dark blackish diorite exposed in low hillocks on the west side of the road to Menominee, in the N.E. quarter of the S.W. quarter of Sect. 26. A part of the rock is almost aphanitic; another is composed of quite large crystals of dark brownish green hornblende, with scarcely any feldspar in the combination. The lighter white and gray-speckled diorite, which forms the barrier rock at the falls, occupies the central part of the formation. A very fine variety of this rock, of a most perfect crystalline structure, occurs in the S.E. quarter of the N.E. quarter, and in the N.E. quarter of the N.W. quarter of Sect. 35. The upper horizon of the group is formed of light greenish-gray colored schistose or massive very hard felsites, the schistose form of which contains a good proportion of hydro-mica in intimate intermixture with the feldspathic ground-mass; frequently also these felsites are porphyritic by segregation of red feldspar crystals within the body mass, which porphyritic masses resemble a granite, and probably are identical with the granite mentioned as occurring in this vicinity by Major Brooks. Iron pyrites is the never-missing accessory mineral in the composition of all these rocks.

Below Sturgeon falls we find large exposures of the porphyritic felsites, partly of non-stratified massive, partly of schistose structure, as we follow the river across Sect. 1, Town. 38, R. 29, and Sect. 6, Town. 38, R. 28; lower down the exposures are for a while interrupted, and the embankment is formed of loose drift-masses, but some distance off from the river-bed, on the road leading to Menominee, the drift-polished rounded heads of the underlying dark green crystalline diorite can often be observed in the cuts of the road. A half mile below Holmes Creek, in the S.E. quarter of the N.E. quarter of Sect. 20, Town. 38, R. 28, we find on the Michigan side, in the river bluffs, a large succession of well-stratified and banded silico-ferruginous rock-beds exposed, dipping under a high angle east-north-east; they are considerably corrugated, or shattered and recemented into a breccia, consisting of alternating narrow seams of chalcedonic, or also porous cherty quartz, once little colored, whitish or grayish, and then again brightly red or brownish red-colored, by impregnation with hematitic iron oxide; some larger belts of glassy quartz occur interstratified. Above and below this rock-belt, which amounts to several hundred feet, are felsitic rocks in contiguity with it, which on the line of contact are likewise impregnated with hematitic oxide by secondary infiltration from the ferruginous beds, as it appears, as the more distant parts of these are not charged with iron. The incumbent beds are dark greenish-gray, schistose, porphyritic felsites; the imperfectly schistose structure is produced by interrupted linear fibroso-scaly seams of hydro-micaceous and augitic composition, permeating the felsitic ground-mass; the underlying beds are of non-stratified massive structure, light gray colored. Those next the siliceous iron-colored strata are in a state of commencing decomposition; they are absorbent, porous by partial transformation of the felsitic ground-mass into kaoline. The originally white-colored rock is mottled with large dark red blotches by infiltration of these parts with hematitic pigment. Below these porous weathered beds are hard compact felsites of a uniformly light gray color; they contain always some proportion of carbonate of lime, which makes them effervesce with acids, and in close, sparingly dispersed, small black octahedrons of magnetite, or perhaps titanic iron, as they resist the action of acids. Lower down the river these massive felsites, of great thickness, are in contact with pale green, fine-grained homogeneous greenstones, which seem to be a modification of the felsite only, but are by insensible transition also connected with the dark green crystalline diorite, which forms, close by, large islands in the river, and is seen in a much greater display at the Quiver falls, also called Pemenee Bon Won falls. At the lower end of the largest, of the islands, the pale green aphanitic greenstones are well exposed in association with a fine-grained crystalline diorite of green and white speckled color; there also masses of the aphanitic greenstone, porphyritic by red orthoclas crystals, abundantly disseminate through the mass. At the Quiver

falls large hillocks of rock rise with vertical walls from the middle of the river-bed, dividing the stream in three arms, which wind themselves through narrow chasms in the mural rocks, and finally rush down over stair-like offsets in the cliffs to a 60 or 70 feet lower level.

The rock composing the cliffs at the Quiver falls is a dark greenish-gray colored fine-grained diorite. Portions of the rock have a peculiar concretionary structure by segregation of globular nodules in the mass, densely crowded together as in an oolite, only of much larger size, from a small hazelnut to a hickorynut; they consist of a granular red orthoclas in intermixture with quartz. By decomposition of the rock these balls readily separate from the surrounding diorite mass. Below the Quiver falls the exposures of diorite continue for about a half mile downward in this grand style; then for several miles only here and there the rock comes to the surface in little islands in the river, or locally projecting above the drift-covered valley. In the north part of Town. 37 we find again rapids, and with them also large exposures of very coarsely crystalline, dark blackish-colored hornblende rocks, much differing in aspect from the diorites of the Quiver falls. One variety is a black glistening rock composed of a magma of granular crystals of white feldspar and black hornblende, in which mass large crystals of the hornblende are segregated, but Inseparably amalgamated with the inclosing ground-mass, as being formed by the parallel arrangement of the smaller crystals into compound larger ones. Another very beautiful variety is composed of large blackish-green hornblende crystals of. great lustre, in intermixture with a small proportion of red orthoclas crystals. A third variety consists of similar large crystals of hornblende in peculiar intermixture with the feldspathic constituent of the rock. Both minerals permeate each other in the crystals in a mode as if a process of paramorphosis from one into the other were going on. Interstitial between this magma of crystals is a purplish red, dull, earthy-looking but hard mineral matter, principally composed of hematitic iron oxide, which imparts to the rock a showy, variegated aspect; black mica-leaves are sparingly intermingled. In contiguity with these coarsely crystalline diorites we find in this locality quartzite beds and cherty argillitic stratified rocks richly impregnated with hematitic iron oxide, which in all probability are analogous with those occurring up the river near Holmes Creek.

About three quarters of a mile below these outcrops are the Pemenee falls, where an immense body of dark-colored feldspar porphyries comes to the surface in bold cliffs, in the river, and on the borders of the river-bed. The exposures begin a half mile above the falls; the rock is here a genuine granite, composed of a magma of indistinctly defined crystals of red feldspar, with a granular quartzose and partly feldspathic ground-mass, which is pervaded with streaky interrupted linear seams of a dark-green chlorite-like mineral, so often found substituted for mica in the granites of the Marquette district. From this granitic form of the rock, all transitions into an aphanitic homogeneous mass, with a flinty conchoidal fracture, are observable; but this aphanitic dark blackish-colored ground-mass always incloses distantly disseminated, well-defined crystals of orthoclas, or sometimes amygdaloidal rounded nodules, formed of crystalline orthoclas, and, examined with the magnifying-glass, appears no more homogeneous; the light-colored feldspathic susbtance, and the dark-colored chloritic or also augitic or hornblendic components of the mass are segregated to a certain extent into delicate linear seams, which sometimes impart to the rock a sub-schistose structure. This lineated structure of the rock becomes obvious to the naked eyes on weathered surfaces, and proves to full satisfaction the lava nature of this rock; the serpentine torsions and convolutions of these lineations exhibit the flowing motion of the once liquid mass as clear as we see it exhibited in the banded slags of an iron furnace. At the base of the falls I found, in contiguity with the porphyritic rocks, lighter-colored sub-schistose felsite porphyries similar to those associated with the diorite at the Quinnesec or Sturgeon falls; an exposure of the coarsely crystalline dark-colored hornblende rock, found a mile above the Pemenee falls, is observable below the falls in the river-bed. A short distance below the falls the rock disappears under the drift; about a mile below, near the Pemenee farm, we can see in the river-bed an outcrop of a fine-grained dark greenish-colored diorite, which differs from the crystalline fine-grained variety of the porphyry at the falls only by the segregation of hornblende crystals in the mass. I returned to Quinnesec from the Pemenee farm, as I was not prepared to go farther down the river, but from notes made on a former trip ten years ago, I know the occurrence of porphyritic and granitic rocks similar to those at the Pemenee falls, at the Muscongo rapids; they come there in close contact with well-laminated schistose beds, and with coarsely crystalline and aphanitic dioritic rocks. Farther down, at the so-called chalk hills, we find the hematitic quartzites and argillitic strata once more associated with the diorite, as we saw it in two other localities above mentioned. It does not appear in any of these exposures as if valuable deposits of iron-ore were to be found in this group of rock-beds, but it is of great scientific interest to find out by future examinations in which relation these beds are with the dioritic rocks—whether they are a regular link belonging to this group, or whether they are deposits of a younger age incumbent on them, which during the upheaval became entangled between a fold of the dioritic and felsitic rocks. The lithological character of this ferruginous rock-belt is unlike the ore-formation of the Quinnesec mines.

Reviewing what we have seen of the formations along the Menominee River, said to be the youngest of the Huronian group, I again point out the great similarity in the composition and structure of this very large series of rocks with the dioritic formation of the Marquette district; also its intersection by the serpentine group, which in the Marquette district is under similar. circumstances associated with the diorite formation. Further in favor of this analogy is the intersection of the Menominee diorites by porphyritic granite in dyke form, as is the case with

the diorite group of Marquette. These porphyritic granites are on their part in. close relationship with the felsite porphyry of the Pemenee falls, merging by insensible gradations with the granite, which is only a more completely crystallized form of the same lava-mass. On the other hand, there exists not the slightest resemblance between the dioritic rock-belt of the Menominee River and those rock-beds of the Marquette district which represent subdivisions 15 to 20 of Major Brooks.

The exact order in which the different rock-masses composing the dioritic formation succeed each other—whether the dark green diorites of the Twin falls and in other places are the lowest, and the lighter colored diorites at the Quinnesec falls the higher ones—is at the present state of our knowledge uncertain, but it is most likely the case; so the dark-colored coarsely crystalline hornblende rocks exposed a mile above the Pemenee falls may be older beds than those at the Quinnesec falls. The massive belts of this series of altered sedimentary rocks, interlaminated with the schistose members, can, as I think, not all be considered as regular links in the stratified succession; some of these, and particularly the larger masses, as they occur at the Quiver falls, I believe to be intrusive, in the same qualified sense in which I have considered some of the massive dioritic rock-belts of the Marquette district, and still in another sense they represent only a more altered portion of the stratified beds connected with them. Considering the granite on the south and west side of Menominee valley as an eruptive rock, like the porpyhry of the Pemenee falls, I can agree fully with Major Brooks in this part of his chronological system; these rocks undoubtedly came to the surface after all the other Huronian strata of sedimentary origin were formed, as their eruption to the surface caused the upheaval of the others. I therefore have always represented the dyke granites of the Marquette district as actually the youngest rocks in the group, but I suppose this was not the original meaning of Major Brooks' system. In all his stratigraphical descriptions, he has not made a proper distinction between sedimentary succession and interstratification, counting up the beds just as they came in a cross-cut; his Groups VII., IX., and XI. are a proof of this assertion.

It still remains for me to give a description of the country west and north-west of the Quinnesec mining district, which is equally-important by its wealth in iron-ore, and even supersedes the other in the size of its ore-belts. One of the largest ore-deposits discovered is the Commonwealth mine; it has a seam 162 feet wide, of a compact, solid, high-graded ore, in which only a few narrow bands of a more siliceous character occur, which are well defined and easily separable. The Commonwealth is on Wisconsin territory, south of the Brule River; but also on the north side of the river, in Michigan, several equally large belts of the same kind of ore have been discovered, besides a great many smaller ones, and constantly .new discoveries are made by hundreds of explorers roaming over this promising wilderness.

I have previously made the statement that the ore-formation of the Commonwealth mine represents a higher horizon than the Quinnesec ore-formation. Major Brooks places the Commonwealth ore-deposits into the upper part of the Lake Hanbury slate series, but while he considers that as one of the upper members of the Huronian series, I place it, on the contrary, below the Quinnesec ore-formation.

The abrupt termination of the Quinnesec ore-formation, on the east side of the Menominee River, near its junction with Pine River, is very singular. We see for the last time the limestones underlying the Quinnesec ore-formation uncovered in test-pits in the S.E. quarter of Sect. 23; and right across the river, in Sects. 21 and 20 of the Wisconsin town subdivision, Town. 39, R. 19, occur the characteristic sericitic and plumbaginous schists of the Commonwealth ore-formation; the strata strike in the usual west-north-west direction, and dip north in an almost upright position. Some layers are slaty, very delicately laminated, soft argillitic-like, and fissile; silky-shining, gray, or intensely red-colored; others, mostly gray-colored strata, are harder, and consist of granular layers of feldspar in seamy intermixture with sericeous scales. With them occur black plumbago schists, containing irregular glassy quartz bands. No iron was found in the test-pits, which are not far off from the bed of Pine River. The higher part of the hill-side is deeply covered with drift. A mile north from here, in the centre of Sect. 8 of the same town, are, on the height of the drift-covered plateau, the previously mentioned knobs of diorite which form a continuation of the outcrops at the Twin falls. On their south side we find, in immediate contact with them, vertical strata of a greenish-drab colored, rather hard but absorbent schistose rocky weathering rusty brown, and breaking into uneven angular shelly fragments. It consists of a half-decomposed kaolinitic granular feldspar mass, abundantly intermingled with micaceous, or probably chloritic scales. These are succeeded by other somewhat softer micaceo-argillitic beds of an imperfect schistose structure, not cleavable into even slaty pieces; their color is ash gray, or purplish gray, or deep red. With them occur more micaceous or sericitic beds, with a slaty cleavage; the thickness of these strata is hard to be estimated, as they are only uncovered by test-pits. To these follows a large succession of red-colored quartzose beds, partly banded and compact, partly cherty cellulose; interstratified with them occur argillites of a seamy or irregularly dotted variegated lighter and darker greenish and purplish color, produced by a streaky and corrugated intermixture of the variously-tinted clay masses. In this association occur seams of iron-ore in different degrees of purity. Some are more or less contaminated with siliceous or also argillitic matter. The pure ore forms a compact, amorphous, fine-grained mass, with a sub-conchoidal fracture without lustre; its color is dark reddish or purplish brown; scraped with the knife it gives a bright

red streak. With these compact hematitic ores are cellulose concretionary ore-masses associated, which consist partly of a fine-grained compact martite with sub-metallic lustre, partly of hydrated oxide under the form of grape-ore; and not rarely in the cell-cavities of this mixed mass fine large black crystals, like the crystallized iron oxide of the Island, of Elba, are found attached to the side-walls, or grow out from the surface of a stalactitic stem of the hydrated ore, which , proves the formation of these crystals contemporaneously and after the formation of the stalactites.

The Commonwealth mine is about five miles north-west from the test-pits I have just described. One can see from here the spot where it is located. The ore-formation extends, in all probability, from here without interruption to the Commonwealth mine; but the surface is so generally covered with drift that only by boring or digging is information obtainable about the underlying rocks of any part of this country. The Commonwealth mine is in Wisconsin, and fault may be found if I enter into a detailed description of it; but if we want information about the geology of a district we cannot mind State boundary lines; we must pick up information where we best can; and here is certainly such an occasion. The Commonwealth mine is not far from the centre of Sect. 34, Town. 40, R. 18 (Wis. Surv.); it is on the plateau-like summit part of a ridge, declining on the north side toward the Menominee River, just about three miles south of the mouth of the Michigamee River. The south side of the ridge slopes down to the Pine River, distant about four miles. Under a cover of from 4 to 8 feet of drift, the ore-bearing rock-series can be found most everywhere on the summit part of this ridge; the strata are near to a vertical position, and dip south. A belt of solid hard ore 162 feet wide is uncovered in the mine, which was incidentally mentioned before; its stratification is very obscure. The extremely fine-grained brownish or blackish purple compact mass, with a dull clay-like fracture, exhibits to the observer the aspect of an extremely fine hardened mud-mass, with the same irregular cleavage into angular small fragments as a piece of dried clay would; by shrinkage of the indurating mud-mass, a great many fissures and little druse-cavities formed within the rock-mass, which are filled or coated over with crystals of dolomite-spar, or with brilliant crystals of iron oxide, or with bright purple scales of micaceous oxide, or with the hydrated grape-ore. The homogeneity of the substance is also frequently interrupted by a partial transformation of the amorphous oxide into a minutely granular crystalline form, with a dull metallic lustre. Portions of the ore-belt are locally found shattered and recemented into a breccia by feldspathic or argillitic seams of reddish or whitish green color, and interstratified with the ore-mass are a few narrow belts of banded ferruginous quartz-beds. South of this ore-belt is a large series of well-laminated schists, blackish-colored by graphita, with interlaminated quartz-seams; some of the schists are so richly impregnated with graphita as to deserve attention regarding their economic value; most of them, however, are very impure, siliceous, or clayey. The thickness of these plumbaginous schists with quartzose seams is very great, as can be observed in the ravines on the south side of the mines, but excepting these, all the other surface south of the mines is deeply covered with drift; therefore, no estimation can be made how far these quartzose-plumbaginous schists may extend southward, and what other kinds of strata succeed them. North of the ore-belt, consequently beneath it, are dark-colored hard siliceous and partially argillitic schists and flaggy layers, richly impregnated with iron oxide; they inclose another seam of good iron-ore about four feet wide. Farther down the slope succeed other dark greenish or brown-colored schists of a siliceo-argillitic character, some with an even slaty cleavage, others cleaving very irregularly into uneven slivers; certain layers are rich in sericitic scales, all contain much iron in the state of protoxide, but become rusty ochraceous by exposure. The larger portion of these schists contains an abundance of lenticular concretionary masses of iron pyrites, which by their decomposition cause the schists to open their laminæ in the above-mentioned slivered mode, and the surfaces of the cleft, still closely coherent slivers, become incrusted with a brightly shining glassy varnish of hydrated oxide of iron of a dark blackish brown color, often also lively iridescent; the little cavities left after the decomposition of the pyrites are filled with brownish yellow ochre. This kind of schists is very characteristic for the Commonwealth ore-formation, as much so as the plumbaginous schists; they occur everywhere as far as this formation extends, and form the largest bulk of this rock-series; they cover the surface of a great many square miles north of the Brule River and south of the Paint River, and by their occurrence the explorer generally knows that he is on ground where an ore-belt can be expected; but he would be greatly mistaken, if he thinks to find the ore-deposits equally distributed in this formation in a certain fixed position. There were certainly periods during the time of the deposition of this group of sediments in which more molecules of iron oxide were carried by the turbid waters which made the sediments, than at others, and the prospects of success in such a horizon are for the explorer generally much better than in another; but one must never imagine that at such a time a uniform sheet of irony deposits formed all over the then existing ocean bottom; the materials were distributed by the currents according to their specific gravity, and according to the velocity and transporting power of the currents; while here all circumstances favored the formation of an ore-deposit, in another place, not a great way off, a stronger current may have prevented the deposition of any sediments, or only allowed the coarser sandy grains to settle down. North of this great belt of schists, which incloses from time to time quartzose arenaceous seams or lenticular masses of quartz, or also a narrow seam of ore, we find another series of dark plumbaginous quartz-schists with interlaminated black and white banded quartzite ledges, which are well exposed in some shafts near the new-built dwelling of Captain Tobin, the superintendent of the Commonwealth mine, to whom I

am greatly indebted for favors and assistance in the prosecution of my work. Some distance east and north of this locality, near the quarter-post on the east line of Sect. 34, are test-pits in which, under a cover of Silurian sand-rock, fine-grained, silky-shining, grayish or intensely red-colored sericitic slaty argillites are uncovered; they dip under a high angle southward, and consequently must be considered as the lower members in the described succession. We find similar beds exposed a short distance farther east, in a brick-yard near the road-side. Farther north are no more exposures. Other test-pits on the south side of this road, in Sect. 35, struck in part soft black plumbago schists, and in part the same sericitic argillites as those near the quarter-post; these two kinds of schist alternate with each other several times, and amount to great thickness, as they are met with everywhere over a space a quarter of a mile wide.

This whole formation, above and below the ore-belt, amounting to not less than 2000 feet of strata, consists throughout of the finest mud-sediments, which have retained their delicate sedimentary lamination most perfectly, even in the slaty rock-beds, whose cleavage is generally parallel with the bedding, and not transverse to it, as in other slate-rocks. West of the Commonwealth mine, in the centre of the S.E. quarter of Sect. 33, on the south slope of the hill-range, is a large belt of the same ore, as we see it in the mine, naturally exposed; the higher part of the ridge north of this ore-mass is formed of nearly vertical ledges of ferruginous and of graphitic quartz-schists. The extension of this large body of ore in east and west direction has not been fully examined yet. In the S.W. quarter of Sect. 32, near the west line, in a number of exploring pits, a large succession of quartzite beds of various character, interstratified with seams of a rich coarsely granular, somewhat magnetic ore of metallic lustre, has been exposed; some of the quartzite beds inclose a large proportion of the crystalline coarse ore-granules; others are purely quartzose, also banded beds of alternating ore and quartz-seams occur, and with them fine-grained dark greenish or blackish siliceo-feldspathic, very compact hard rock seams, which contain a large proportion of iron. In the western pits are well-laminated hard, hydro-micaceous feldspathic schists exposed, some of which are beautifully mottled with copper-colored irregular blotches on the dark purplish gray ground-mass; others are light greenish yellow, and resemble the novaculitic schists of the Marquette district. The strata are nearly vertical, seem to dip southward; on their south side, in test-pits and by natural exposures, the plumbago schists interlaminated with quartz seams are to be observed, and on the north side of the exploring pits red and grayish purple sericitic slaty argillites occur, similar to those on the north side of the Commonwealth mine. About a quarter mile farther west, in the S.W. quarter of Sect 31, south of the road, are high bluffs of a compact light reddish-colored quartzite.

The Florence mine, situated in the S.W. quarter of Sect. 21, Town. 40, R. 18, corresponds with the Commonwealth mine in the character of the ore-belt and the rocks associated with it, as well as it can be expected in localities two or three miles apart; the strike of the formation is about the same as that of the Commonwealth, but its dip is opposite, northward. The ore-belt is considerably shattered on the surface, but is also very large, over a hundred feet wide. A part of the ore is very compact, finely granular, of dark steel-gray color, with a dull metallic lustre. The largest quantity of the ore presently mined is a compact amorphous dark shattered mass, full of fissures and little cavities filled with soft ochraceous oxide of yellow color, or incrusted with grape-ore. Larger stalactitic masses of hydrated grape-ore are quite abundant, and these grape-ore stalactites are often covered with black solid crystals of oxide, and with micaceous iron oxide, transparent with deep purple color. Interstratified between these ore-deposits are some quartzose seams and a belt of green and red mottled rather hard and compact argillite. South of the ore-belt, therefore beneath it, follows a series of siliceous ores, too low-graded to be used, and then succeed the hard dark blackish-colored and rusty yellow or brown weathering siliceo-argillaceous, pyritous schists, varnished over with a glassy coating of hydrated oxide of iron, which I have described as occurring north of the Commonwealth mine, and which, to avoid the lengthiness of description, I will in future only call *pyritous schists*. Above the ore-belt, on the north side of the hill, are graphitic schists with quartz seams, and abundantly disseminated with iron pyrites. Farther north the strata are hidden by drift-deposits, but west of the mine is a large number of test-pits partly opened by the Florence Mining Company, partly by Mr. Harvey in Sect, 20 and Sect. 17. The graphitic schists are there not immediately on the ore-belt, but red iron-colored micaceo-argillitic or harder feldspathic schistose, or slaty beds intervene. The ore-belt of the Florence mine does not seem to extend in this direction in equally large dimensions, but narrower seams of rich ore, interstratified with leaner siliceous ores and with quartzite seams, are found in its place. North of the graphitic schists succeeds a large series of sericitic schists, some dark red-colored with hematite, others lighter grayish, or almost white; their ground-mass is partly a hard granular feldspathic mass, partly kaolinite. These strata resemble the sericite schists north of the Commonwealth mine, which appear to be below the ore-formation, while those are clearly above it. Two different belts, a lower and a higher, of deposits of this kind seem to exist, but possibly they may represent the same horizons and have come into such positions by plication or an overturn of the strata. I have so far not been able to decide this question, but as the miner is often guided in his explorations by these schists, it is of great practical importance to ascertain positively whether there are two distinct horizons of schists so similar to each other, or only one.

A very interesting field for observation of a different, most likely lower, horizon of the Commonwealth ore-formation is found on the north and west sides of Keyes

Lake, in Sects. 25, 24, 23, 27, and 28, in Town, 40, R. 17. Besides a good many natural exposures, the great number of test-pits recently opened there have brought to light a great variety of rock-beds, but the order in the succession of these strata is not clearly recognizable, as the denudations by the test-pits are too much disconnected, and the frequent change observed in the dip of the strata indicates the existence of many plications of the rock-beds, causing their repetition in the different localities. We observe, in the S.E. quarter of Sect. 25, a large belt of vertical quartzite ledges over 200 feet in width, which can be traced to extend in a north-west direction across Sects. 24, 13, and 12, to the Brule River. A part of this rock is compact, light-colored, and resembles the quartzite exposed at the falls of the Sturgeon River, but the much greater portion of the rock occurs in thinly laminated schistose, very compact thick ledges, which schistose structure is due to the copious intermixture of linear hydro-micaceous laminæ with the granular quartz-mass. On the south side this quartzite belt is adjoined by an equally large succession of alternating quartzose and actinolitic seams of a dark color, in rough, irregular, somewhat shattered and recemented layers; the quartzose seams are partly compact in banded, streaky, or reticulated seamy intermixture with granular magnetite, or uniformly disseminated with larger or smaller proportions of it, partly porous saccharoidal, particularly the narrow bands of quartz wedged in between the actinolitic rock-masses. The actinolite forms very tough uneven layers, composed of a dense agglomeration of globular clusters of radiated, delicately fibrous crystals, generally blackish-colored by intermingled granules of magnetite, but not rarely it is not tinged, whitish, of silky lustre. Single radiated globular masses of actinolite are often seen dispersed within the substance of the sandy quartz-seams, in contact with an actinolite seam. South of this actinolitic rock-belt, which occasionally incloses narrow seams of granular magnetic ore, succeed hard dark blackish-colored, fine-grained slaty rocks in various modifications; their black color is due to graphitic matter, partly to granular magnetite, which usually is found dispersed through the siliceo-feldspathic hydro-micaceous ground-mass which composes all of them. Farther west and north, but south of the quartzite belt, in Mr. Burt's test-pits, in the S.E. quarter of the S. W. quarter of Sect. 24, we find a large succession of quartzose and argillitic, rather hard rock-beds, all of which are more or less richly impregnated with hematitic oxide; associated with these are black plumbaginous schists of soft or harder siliceous nature. The strata in this location dip north, arid in some test-pits they are almost horizontal; in others they are steeply inclined.

Interlaminated with these beds are various smaller seams of valuable iron-ore, in compact aphanitic masses of blackish purple color, or in the form of grape-ore, in partly hydrated, partly not-hydrated condition; also actinolitic seams richly impregnated with iron, and usually in a porous, earthy, decomposing condition, are found in these test-pits. In the S.W. quarter of the S.W. quarter of the same section white and reddish speckled porous kaolinitic beds of considerable thickness are found in the bottom of the pits, which might represent a decomposed dioritic rock. The most promising iron-ore seams are found in the test-pits of Mr. Tobin, in the N.W. quarter of the S.W. quarter of Sect. 24, where, in association with the quartzitic and argillitic ferruginous beds, rich layers of an earthy compact hematitic ore occur. In which a great quantity of large octahedric crystals Is disseminated. As in the same mass also dim fibrous crystal groups of actinolite, transformed into a soft yellow ochraceous substance, are found imbedded, it becomes evident that the amorphous red hematite, Inclosing the crystals, is a product of alteration of the rock by higher oxidation of the ground-mass, which has not yet affected the crystals. In the S.W. quarter of the S.E. quarter of Sect. 24 occur compact sub-magnetic ore-seams of dull metallic lustre, imbedded within actinolitic quartz schists, which evidently represent the fresh unaltered condition of these hematitic earthy ores, with inclosed magnetite crystals; the steel-gray minutely granular mass exhibits the large octahedric crystals plainly. A short distance north of these test-pits the mural walls of the large quartzite belt ascend to form the summit of the range; north of the quartzite are no more rock exposures. In test-pits opened in the S. E. quarter of the N.W. quarter of Sect. 25, the schists of this ore-bearing group are intersected or interlaminated by a doleritic rock-seam in a softened, decomposing condition, which totally differs from the dioritic rocks of this region, and completely resembles the doleritic dyke-rocks of the Marquette district; the augite crystals are dark brown, not fibrous, but like basaltic augite; the feldspar crystals have lost their glassy lustre, and have become pale brownish by imbibition of hydrated iron oxide. The denudations are not sufficient to see whether this dolerite belt is parallel with the strata, or whether it Intersects them transversally. In the S.E. quarter of the N.E. quarter of Sect. 23 are other test-pits, opened by the Union Iron and Steel Company, in which generally light whitish or greenish-gray and red-colored sericitic and argillitic schists, associated with graphitic belts, have been found, but no promising seams of iron-ore.

Following the road from Keyes Lake to Wakefield's explorations, we see near the south comers of Sects. 25 and 26 exposures of highly ferruginous actinolitic schists, inclosing granular quartz-seams. Farther on, near the quarter-post, on the south line of Sect. 26, these schists are in close contact with a fine-grained dark greenish-black colored rock, consisting of a minutely granular feldspathic ground-mass of a pale whitish color, in intermixture with a scaly mineral, which is probably chlorite, and with a great abundance of small needles of black turmaline. Farther on, near the N. E. corner of Sect. 34, the graphitic schists are well exposed, and south of them follows a large succession of the actinolite schists with quartzose sandy seams, and with others of a compact magnetic ore, of partially actinolitic structure; all these beds are so near to a vertical position, that nothing definite can be said about

their dip. Going here off from the road in a north-west direction, we come over swampy grounds, with numerous exposures of dioritic rocks projecting above the surface in low hillocks; they consist of quite large, well-discernible crystals of green hornblende, with an interstitial white feldspathic mass. In the S. W. quarter of the N. W. quarter of Sect. 27, test-pits are opened in actinolitic schists in a vertical position, which are interlaminated with quartzite seams and cellulose cherty belts, besides narrow seams of a compact crystalline, somewhat magnetic, iron-ore, which thin flaggy ore-layers inclose quite a number of brownish red garnet crystals. The actinolite schists in this place have been cross-cut by trenches about 150 feet, which at each end struck a belt of diorite in close contact with the vertical rock-ledges; the portions of the diorite next to the actinolite schists are in a weathered, friable condition; farther off the fracture of the diorite is bright, fresh, perfectly similar to the diorite outcrops in the swamp. In the adjoining part of Sect. 28 are other test-pits, in which the actinolitic schists come likewise in contiguity with the dioritic rocks, believed by Major Brooks to be incumbent on the schists, but evidently intrusive masses, which is clearly evinced by the occurrence of a belt of ferruginous actinolite schists 150 feet wide, intermediate between two large bodies of diorite, on the other side of which again the actinolite schists come to the surface. From all observations I had occasion to make, I infer the age of the actinolitic rock-series to be older than that of the productive ore-belt of the Commonwealth mine, but both belong to one and the same group of deposits.

Going north of Florence we find, on the north-west shore of Fisher Lake, outcrops of a fine-grained massive, and partly schistose diorite; all the surrounding country is covered with drift. On the road leading to the Brule River similar diorites are seen extensively exposed on the height of the hill-range in Sect. 16. The very steep descent to the river is all drift-covered in the place where the road goes, but farther east the slope toward the river is full of rock-cliffs, as I could see from the opposite side.

I have mentioned the occurrence of large exposures of mica schists, and of harder, compact, fine-grained gneissoid rocks in Sect. 12, on the north side of Brule River, near its junction with Paint River; we leave these on our east side and follow the road westward, parallel with the course of the Brule. For six miles nothing but sand or boulder-drift is to be seen, while we pass over the undulating highlands bordering the river; finally, in Sect. 31, Town. 42, R. 32, after crossing a small creek and ascending a very steep hill-side, we find it composed of the schists, which for brevity's sake I proposed to name pyritous schists on a previous page. They are almost vertical, and dip on different parts of the hill in different directions. Onward to Brown's trading-post, in the N.E. quarter of Sect. 36, Town. 42, R. 33, we see on every hill-slope of the very broken country these schists exposed, until we have descended into the valley of the Brule. Taking from here a northern course, we find the schists again exposed, or merely covered by a thin coating of soil, on the brow and summit of the hills in Sects. 25, 24, and farther north; in fact, ignoring the loose drift -masses, these schists form the exclusive surface-rock of the town we are in, and of the adjoining towns, with very few exceptions, where in circumscribed narrow spots lower rock-beds reach the surface. The extension of these steeply upheaved beds over so large an area naturally implies their often repeated plication, which folds are not only often obliterated by compression of the curved sides into a parallel, conformable position with each other; but even where this is not the case, the loose superficial masses of drift and soil hide the beds so much that in any of the exposures we find or make by artificial denudation of the beds, we can rarely make conclusions on the succession of the beds from their dip in a certain direction, as we have rarely occasion to observe the complicated flexions of the strata, which reverse the order of things at once; and therefore we have in most instances to decide by the character of the rock-beds whether we ascend or descend in the series by going in a certain direction.

Passing on the road northward across Sects. 25 and 24, small outcrops of the schists and interlaminated jaspery quartzose seams frequently occur; particularly well they are exposed in a ravine in the N.E. quarter of Sect. 24, where the beds are quite ferruginous and gave inducement to the opening of some test-pits in this place, but no ore-seam of any value could be found. Subsequently test-pits were opened by Mr. Porter 400 or 500 steps south-west of that locality, in which graphitic schists interlaminated with banded quartzose ledges of ferruginous character occurred; the strike of the strata is north-west, their dip under a high angle north-east. From these pits a row of other pits and trenches was dug southeastward, crossways to the formation, in which a variety of siliceous, argillitic, and graphitic beds, amounting to a very great thickness, were intersected, all of which contained a larger or smaller proportion of hematitic oxide, and some narrower seams of a fair quality of hard ore, similar to the Commonwealth ore, had been found inclosed at the time I visited the place; and later, after my return to Ann Arbor, the proprietors informed me of their final success in discovering, by extending the test-pits still farther south, a large belt of a compact dark purplish brown aphanitic ore of an excellent quality, as the specimens sent to me prove it. North of Porter's pit, near the Hue between Sects. 24 and 13, we have to descend into a swampy valley, in which several low hillocks project, which are composed of a fine-grained massive diorite. Leaving the swamp and ascending the hills farther north, we meet, in the north half of Sect. 13, again with the ferrugino-siliceous schists and banded jaspery beds we found near Porter's camp. East and west of us are crests formed of the nearly upright ledges of this rock-series; arrived at the top, in a saddle-shaped, swampy depression between these crests, we discover a hillock, about 12 feet high, rising from the middle of the low ground, covered with quite thick deposits of bog iron-ore, and coming up to it we find it composed of solid iron-ore, the same as the Commonwealth ore, in intermixture with some jaspery

seams confined to a certain limited part of the ore-belt, which strikes approximately north and south. The width of this ore-mass is about 70 feet; the length of the exposure 300 or 400 feet; south, in the direction of its strike, we find only the ferruginous quartz schists; north is a swamp; and east and west the same kind of ferruginous quartz schists occurs, which generally forms the surface of the country. This ore outcrop, claimed to be first discovered by Mr. Jac. Armstrong, one of the prominent explorers of this region, is named by him, on account of its large size, the Mastodon mine.

West of the Mastodon mine, near the S.E. corner of Sect. 11, Mr. Bond has opened test-pits in this siliceo-ferruginous schist-series; the strata are in places vertical, in others they dip south, and locally I found them almost horizontal. The southern strata near the corner of the section are principally banded, fine-grained, or flinty siliceous rocks, some of which bands are richly impregnated with iron oxide of dark brown color on the outside; the inner, not-weathered parts are blackish, as they contain the iron oxide in a not-hydrated magnetic condition. These beds inclose irregular seams of a good quality of ore, like that of the Mastodon; but none of those I saw were large enough to be of great practical value. In the north part of the section the structure of the rocks is more slaty, in a degree argillitic, yet rich in iron; but no ore-seams are found in it. From Sect. 11 I went north-east into Sect. 1. Near the S.W. corner of Sect. 1 are quite extensive exposures of these slaty ferruginous strata to be seen in the bed of a creek; they dip south, or are vertical. All the surface of Sect. 1 is composed of the same siliceo-ferruginous slates and schists, in alternation with large belts of graphitic schists, and occasionally a narrow seam of hematitic ore is encountered, but none of any larger bulk has been found, although a great amount of work has been done here by explorers. North of Sect. 1, in the N.W. quarter of Sect. 31, Town, 43, R. 32, Mr. Sheldon and Mr. Schaefer have had more success in their explorations; a very large body of ore-beds, amounting to over 150 feet in diameter, has been uncovered there, which resembles the ore of the Commonwealth mine, but is less free of siliceous seams interlaminated with the ore-mass; some slaty strata, almost rich enough in iron to be used as an ore, are exposed on the north side of the ore-belt, but no other rock-beds are denuded there in connection with the ore-belt, which stands vertical. In the bed of the creek crossing the south part of Sect. 31, and of Sect. 36 of the next township, are outcrops of a middling coarse-grained crystalline diorite; the hillsides round it are all drift-covered.

From these northern exploring pits I returned to Porter's camp, in the N.E. quarter of Sect. 24, and went from there across to the N.W. quarter of Sect. 23, where likewise some explorations for iron-ore have been made, but the drift-deposits are there most too thick for the explorer; some of the pits had to be dug through 60 feet of this loose material before the rock-ledges were struck; the work has for this reason been abandoned. The extension of the schists of the iron-formation over this part of the country is fully evinced by the rocks thrown out. of these test-pits, and by several natural exposures found there. Farther west, by following the road to Lake Chicagon, from time to time rock-ledges of the same kind are found locally denuded from the drift, which generally forms the surface of the surrounding lands. Such exposures are met with in Sect. 28, on the brow of an extremely steep hill-side sloping down to Armstrong's Creek. The schists in upright position form the higher part of the slope, and the basal portion is formed of bulky dioritic rock-masses. From there to Chicagon Lake, and thence to Iron River, in Sect. 36, Town. 43, R. 35, along the road no rock-ledges can be seen at the surface, formed of a coarse boulder-drift in which granitic and dioritic blocks largely prevail over other kinds of rock. In the valley of Iron River we find the iron-formation again well exposed in the hill-sides bordering it. In several places larger masses of ore were naturally exposed, which discovery attracted a number of exploring parties, who are at present earnestly at work in digging test-pits. The explorations of Mr. Sheldon are going on in the west half of the north-west quarter of Sect. 36; the strata are there considerably shattered at the surface, and it is difficult to ascertain their exact strike and dip, but in the bottom of the pits they are more regular, and dip under a high angle north-eastward. A large mass of iron-ore, entirely similar to the ore of the Commonwealth mine, is naturally exposed in the S. E. quarter of the N.E. quarter of Sect. 35, but following the line of strike of this mass, which is approximately north and south, parallel with the course of the river in this place, we soon lose sight of it, and test-pits opened in the same direction did not meet with a similar ore-mass. Above and below this seam of ore are siliceo-ferruginous and partly argillitic strata of great thickness; below it are, conspicuous, in particular, banded layers formed of alternating seams of white, or gray or brownish flinty quartz, and of others consisting of a fine-grained, compact, more or less siliceous ore. These flinty ledges are often brecciated, but do not represent an accumulation of different kinds of rock-fragments cemented together, but merely the shattered flinty quartzite strata, which often are not much dislocated, and have often the corresponding broken ends of the fragments right opposite to each other; their interstitial cement is a granular quartzose mud-mass, impregnated with hematitic oxide, or almost totally consisting of the oxide.

In the test-pits farther up on the river side, in the N. W. quarter of the N.W. quarter of Sect. 36, which are opened in a somewhat higher horizon of the series, argillitic strata prevail over the siliceous; some are well-stratified banded ledges, variegated by the alternation of non-tinged whitish or greenish seams, with others intensely red-colored by hematite; others are of uniform color, red, or gray from impregnation of martite granules, or black from graphita in their composition; also mottled argillites are found in this association of brecciated structure, or else consisting of an imperfect intermixture of argillitic masses of different color, when in a plastic condition. Interstratified with these occur hematitic ore-

masses, in pockets rather than in regular seams, and also un-homogeneous in their mass, as if crushed and baked together again; a part of the hematite-ores is soft, paint-like; another part is a hard, compact, amorphous mass, with intermingled crystalline ore-granules, and coated over with oxide crystals on the walls of little cavities in the ore. The massive ore-belt naturally exposed in Sect. 35 has its numerous irregular druse-cavities lined with brush-formed clusters of needle-shaped crystals of goethite, which are translucid, with a brownish purple color, similar to the color of iron mica in thin leaves; other cavities are incrusted with ordinary hydrated grape-ore. By going direct east from this natural ore-exposure unto the plateau-like top of the hill-range, we find a large belt of vertical ledges of a fine-grained, compact siliceous rock of a sub-schistose structure, which incloses a large proportion of disseminated minute granules of magnetite; its color is almost black, which may in part be due to an intermixture of fine molecules of graphita. Noteworthy is yet the occurrence of large rounded chunks of a high-graded schistose specular ore in the drift-masses, which are foreign to this ore-formation, and must have been transported from some northern locality representing another group of ore-bearing rocks, similar to those of the Marquette district.

On the west side of the river, opposite the described test-pits in Sect. 35, are high bluffs, some distance backward from the river channel, formed of the dark blackish-brown siliceo-ferruginous schists, with slivered, uneven cleavage, interlaminated with more compact ledges of the same siliceo-ferruginous composition, which series of rocks is all over the country characteristic of this formation, and composes the largest bulk of it. The strata are almost vertical. A half mile north of these bluffs the river bends at a right angle to the west across the centre of Sects. 26 and 27. In some parts of the generally drift-covered hill-slope, on the south side of the river, we find the flinty siliceous rock-beds, banded with seams of siliceous iron-ore and brecciated, corresponding with those first described, as occurring below the large naturally exposed ore-belt on the other side of the river; the interstices between the siliceous fragments are usually filled with seams of grape-ore; the strata dip under a high angle south, and on their south side a thick series of light yellowish-colored fine-grained calcareous quartzite strata succeeds them conformably.

South of Mr. Sheldon’s location Mr. Wood has opened test-pits, in the S.W. quarter of the S.W. quarter of Sect. 36; the strata are, as in the other location at the foot of the hill-slope, a banded, partially brecciated flinty quartz rock, recemented by ferruginous matter of greater or lesser purity. Above are rich deposits of ore, in irregular pocket-like, dilating and contracting seams, the ground-mass of which ore is amorphous, compact, hard, like the ore of the Commonwealth, but full of druse-cavities lined with a thick incrustation of ordinary hydrated grape-ore, or of the darker-colored goethite, or with thick rhomboid crystals like the Elba island ore, or with all the three forms of the oxide at the same time. Large bulky masses of this ore are exclusively formed of long stalactitic stems of goethite, or the ordinary grape-ore; some with the lustre of a mirror, others with velvet lustre. Above the ore, on the higher part of the hill, are argillitic and graphitic schists, associated with the quartzose seams; farther on, near the edge of the summit plateau, are the dark rusty-colored ferruginous quartz schists, typical of this iron-formation. The recognition of the order in the succession of the beds, which in different localities so little corresponds, is almost impossible, on account of their imperfect denudation and the great dislocation of the strata by plication. Examining the west side of the river, down stream, along the section line between Sects. 1 and 2, Town. 42, R. 35, I found the ferruginous schists, seen in the river bluffs in Sect. 35, again exposed in the N.W. quarter of the N.W. quarter of Sect. 1; but farther south all the surface is covered with drift. On the line between Sects. 11 and 12 no outcrops can be discovered. Going from the S.E. corner of Sect. 11 to the centre of the N.W. quarter of Sect. 13, a low undulating elevation striking north-west is found to be composed of a gray and white speckled diorite, very similar to the diorites of the Quinnesec falls. Taking from the diorite ridge a north-north-east course through the swampy valley of the river, and crossing it, we find bluffs of the ferruginous schists interlaminated with quartz-seams, inclosing narrow bands of siliceous iron-ore. These slate exposures can be followed all along the west line of the N.W. quarter of Sect. 12 into the S.E. quarter of Sect. 1, where the strata strike west-north-west, and dip toward the south. From here I went across the north part of Sect. 7, where the ferruginous quartzose schists are again exposed, but the surface of the greatest part of the hill-lands over which I passed, striking northward for the wagon-road to Mr. Sheldon's camp, is covered with drift. I mentioned on a former occasion the occurrence of large limestone bluffs on Brule River, in Sect. 19, Town. 41, R. 16, of the Wisconsin Town Maps. The limestones, of a siliceous character, in thick massive beds, amounting to a belt of 400 or 500 feet, have a vertical position; south of them are no exposures. The rock-ledges disappear under drift-masses, but at a distance of about a quarter mile south of the limestone another parallel undulating ridge is composed, of a peculiar dark-colored rock, consisting of an aphanitic feldspathic ground-mass, intimately mingled with a minutely scaly, hydro-micaceous or chloritic mineral, in which mass glassy grains of quartz are abundantly dispersed, besides amygdaloidal masses of ferruginous calcspar and of single feldspar crystals. North of the limestone bluffs are also no other rock-strata seen in contiguity with them, but across the river on the Michigan side the schists of the iron-formation, in a vertical position, are well exposed. The limestone bluffs extend on the Wisconsin side about three quarters of a mile down the river, and then, after a short interruption of the outcrops, we find the ferruginous and graphitic schists with flinty quartz-seams extensively exposed in the river-bed, and in the embankments on the Wisconsin and Michigan sides. Some distance lower down the river massive and schistose dioritic rocks come

to the surface; they form high bluffs on the Michigan side, in the N.E. quarter of Sect. 23, and are traceable for quite a distance northward off from the river. The massive dioritic beds are fine-grained, pale greenish or dark green, by chloritic intermixture; they inclose an abundance of small calcspar crystals within their mass, and weathered surfaces of the rock are therefore full of little cavities, once occupied by the spar.

I have come now to an end with the record of my explorations in the Menominee River district during the summer season of 1880. Within the given time I was unable to see the whole of this interesting country; and even the part I did see, I could not always examine with the accuracy, necessary for a complete understanding of the order in the succession of the greatly dislocated rock-beds of certain localities; and with the best will to make an exhaustive examination of such places, it could not have been successfully done, without having first acquired the knowledge of the general structure of the whole district, which to obtain was my present object. Having quietly looked over and described the results of my examinations, I see now clearly the deficiency of my information in certain points, some of the wants in knowledge could have been supplied at the time I made the observations; but an observer seeing new things of interest often becomes so absorbed by the thing itself, that he forgets to inquire into the relations it has to others surrounding it, because he is not aware at that moment of their importance.

Having described the rocks of the Marquette district and of the Menominee iron region in two independent chapters, it remains for me to answer the very important question. What relation exists between the rocks of these two districts? In accordance with the generally adopted opinion of geologists, I consider the upheaved stratified rock-series of the Marquette district, which reposes on granitic rocks, and is overlaid by horizontal Silurian sandstones, as analogous with the Huronian group of the Canadian geologists, I leave It undecided whether an analogy exists between the granites of the Marquette region and the Laurentian rocks of Canada; but I claim the granite-belts interstratified with the Huronian formation as decidedly younger, than most of the strata of this series.

The analogy between the rocks of the Marquette region and those of the Monominee Iron region is likewise generally admitted; the two regions are in direct continuity, and only 60 miles apart; still very few of the rock-beds of the two are identical, and even the different groups of strata do not exactly correspond.

The dioritic rock-group of Marquette, as has been previously stated, is considered by me as the analogon of the dioritic rock-series exposed in the different falls of the Menominee River, for reasons already stated. The felsite porphyry of the Pemenee falls I compare, in its relation to the dioritic group, to the Intrusive granite-belts of the Marquette district. An analogon of the iron-formation of Marquette is found in the Quinnesec Iron range. The quartzite formation of the Teal Lake range, and the quartzites connected with the ore-bearing rock-series, might be compared with the great quartzite formation of the Sturgeon River falls. The occurrence of a large limestone formation above the Quinnesec ore-formation, which has great similarity with the limestone formation exposed in connection with the quartzite ranges south of Marquette, seems to be contemporaneous with these, but the limestones of the Menominee district are always separated from the quartzite by a wide interval, while the limestones of Marquette are Inseparably-connected with the quartzite formation merging with it. The ore-deposits of the Taylor mine, S. C. Smith mine, and of the lately opened Northampton and D'Alaby mines in the Marquette district, which occupy the higher part of the fifth group in my adopted system of subdivision of the Huronian group, are evidently analogous with the Commonwealth ore-formation, and the actinolitic part of that series of strata finds its counterpart in the actinolite schists underlying the Northampton ore-deposits and overlying the quartzites of the Michigamee and Spurr mines. The Lake Hanbury series occupying the place of the lower actinolite schists below the ore-belt of the Washington and Republic mines has no lithological resemblance with these beds.

Whether the Felch Mountain ore-formation is analogous with the Quinnesec ore-formation, and the crystalline limestones, charged with tremolite crystals, correspond with the limestone formation connected with the Quinnesec ore-belt, I am not ready to decide; the similarity of the rocks of these two ore-formations is much greater, than it is between either of them and the Commonwealth ore-formation. I desist for the present from an attempt to make more special identifications, as by future examinations much is yet to be learned, before the suggested analogies can be proved. A forcible systematizing, as has been attempted in a tabular exhibition of the equivalency of Huronian rock-beds, in my opinion, does more to confuse a person than it helps to enlighten him.

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."