ores could be found. A similar costly experiment, which likewise proved to be a failure, was made in the S.W. quarter of Sect. 27, Town. 48, R. 26, at the so-called Sedgwick mine, where a quartz vein carries a small quantity of copper pyrites. Considerable test-pitting has also been done in examination of a quartz-vein containing carbonate of iron and some copper pyrites in Sect. 25 of the same township, a short distance north of the Morgan furnace, but with no better success. A good many other localities could be enumerated in which explorers spent weeks and months of hard labor to follow such quartz veins, in which they discovered a few nodules of copper ore or galena. The most promising veins of argentiferous galena have been discovered in the granite hills near the head-waters of the Chocolate River. I have seen there, some years ago, many tons of pure lead-ore piled up on the side of the test-pits, but it seems as if these also are abandoned at present. It can safely be asserted, from precedent experiences, that the Marquette district is, with exception of its immense wealth in iron-ore, rather barren of metallic ores of another kind.

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 ferruginosiliceous 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 groundmass, 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 will 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 Stephenson 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-hydromicaceous 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 reddish, 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 spar. 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 more 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 seams 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 dio-

ritic 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-formation;* 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 sandrock 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 south-west 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, differ-

ent 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. cor. 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 orthoclas, 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 sericite 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 hill-side 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 dip 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 quartzoso-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 information 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 cellulosoporous 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 groundmass 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,