CHAPTER VI.

MICA-SCHIST FORMATION.

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

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

This evidence consists in the clear recognition of typical garnet and staurolite-bearing mica-schists, on the north side, and conformably underlying the graphitic and limonitic group of rock beds, which northern belt of schists lithologically is identical with the mica-schists on the south side of the belt of graphitic and ferruginous rocks. This seeming repetition is accounted for

by a folding of the layers by which the incumbent youngest strata became wedged into a synclinal depression of the older.

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

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

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

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

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

The strata exposed north of the island, on the main shore, are graphite-schists and actinolite-schists, impregnated with a good proportion of magnetite. These beds likewise dip north and represent the lower portion of rock complex, which higher up in the series incloses the limonitic ore deposits; it corresponds with the strata exposed at the Champion furnace. At the extreme east end of Michigamme Lake almost vertically erected, very much corrugated, well laminated rock ledges crop out, dipping to the north, which, in their lithological character, correspond with the mica-schists. The strata on the north side of the railroad track at this place, belong to the lower series of the Northampton mine rock-complex. The mica-schists in all probability continue eastward past the Champion mine, occupying the bottom of the valley, but are not exposed; the underlying series

of the rock beds of which above a description is given, is traceable on the southern row of hills, all along unto the Keystone mine, where the group of beds is extensively exposed. The large rock bluffs in Sec. 4, T. 47, R. 29, on the south side of the railroad, which I have previously described as well laminated compact gritty rocks, consisting of a micaceous quartzose and feldspathic groundmass, which generally contains also a good proportion of carbonate of lime and in certain seams is crowded with green hornblende crystals, in many respects resembles certain belts of the mica-schists exposed on the islands in Michigamme Lake; their stratigraphical position corresponds with that of the mica-schists. Tracing these rock belts farther east, their lithological character changes more and more, and the horizon of the mica-schists is no more recognizable.

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

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

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

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

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

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

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

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

Higher up in the series, the schists have a dark greenish steel-

color, with considerable lustre; their color is due to the green color of the biotite scales in the rock substance.

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

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

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

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

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

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

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

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

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

CHAPTER VII.

KEWEENAW GROUP.

(A) GENERAL CONSIDERATIONS.

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

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

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

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

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

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

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

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

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

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

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

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

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

(1) STRUCTURE OF THE KEWEENAW GROUP IN GENERAL.

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

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

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

But reading their own descriptions and those recently published in Mr. Irving's excellent work on Lake Superior rocks, I find, as the latter does, a perfect lithological resemblance of these schistose layers with the group of beds which occurs on the south shore of Lake Superior and constitutes the upper horizon of the Huronian series, without contradiction from any side. Of the identity of this lower rock belt of Thunder Bay, with the

upper Huronian rocks in Michigan, I became still more firmly convinced, after I had occasion to observe a continuation of this Thunder Bay series into the State of Minnesota, while crossing from Agate Bay to Vermillion Lake. The exposures observable on this route, do not only correspond with the descriptions given of the Thunder Bay series, but are at the same time a perfect counterpart of the upper Huronian of Michigan.

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

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

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

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

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

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

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

Prof. Pumpelly, while engaged by the Michigan Geological Survey for the examination of the Copper district, devoted his work principally to the examination of the Portage Lake and Eagle River districts, and published in the first volume of Michigan reports a great many detailed cross-sections and maps,

based on the records of the explorations made by the different mining companies; partly also such sections, with accurately measured distances, were the work of his own and his assistants. One of the largest of these, elaborated by Mr. Marvine, is the section from Eagle River to the Phœnix mine; it comprises a succession of about 8,000 feet of strata.

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

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

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

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

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

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

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

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

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

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

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

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

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

(2) SOUTH SIDE OF PORTAGE LAKE.

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

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

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

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

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

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

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

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

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

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

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

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

Several conglomerate belts are also exposed within this space, of which the one next to the brewery is the largest. They all consist of mostly quartzless, red colored porphyry pebbles, some

of the size of a man's head; part of them are a compact crypto-crystalline felsitic mass, others are perfectly composed of red feldspar crystals with scaly masses of a dark green mineral scattered between, which under the microscope proves to be more or less altered hornblende. Less common in the accumulation of pebbles are such of a fine-grained dark diabase, in whose groundmass large crystals of red feldspar are segregated; also coarsely crystalline masses of olivine-bearing and hornblende-bearing gabbro are found among them.

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

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

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

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

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

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

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

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

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

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

3. NORTH SIDE OF PORTAGE LAKE.

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

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

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

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

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

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

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

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

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

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

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

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

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

West of the shaft, exploring trenches have been dug across the property to its boundary lines, in which an alternation of compact and amygdaloidal diabases is laid open, besides two interstratified conglomerate belts and sandstone layers. A third conglomerate belt much wider than the two former, crops out a short distance farther west, then succeeds a large belt of

amygdaloidal rock with unusually large irregularly-shaped anastomosing cavities filled with chalcedonic and crystalline quartz with porcelain-like datolite and delessite. This belt is much shattered and recemented into a breccia by quartz and spar seams; it contains not enough copper to be of practical value. The three mentioned conglomerate belts are likewise cupriferous, but the amount contained is small.

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

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

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

4. NORTHERN PART OF KEWEENAW POINT.

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

This fact has been contradicted by Dr. M. E. Wadsworth, who pretends to have observed in these localities a conformity of the Silurian sandrocks with the Keweenaw rocks, whereby the latter would occupy the highest position and the Silurian sandstones be the underlying older strata. Ascending the narrow ravine through which Hungarian Creek comes down the hillside, forming on its way several cascades, we step over horizontal ledges of a red sandrock identical with the horizontal sandstone ledges exposed along the shore of L'Anse Bay, etc., until vertical rock walls nearly 100 feet high obstruct our progress. The creek leaps over them into the abyss. These high walls are formed of a large succession of horizontal beds of sandstone very similar to the ledges forming the bottom of the creek-bed below. Climbing to the top of the walls by a circuit and following the creek upward, we see the horizontal beds continue for some distance and find them to form several other abrupt offsets, causing cascades from fifteen to twenty feet in height; finally, near the summit of the hill, we observe another cascade about twenty-five feet high, caused by the projection of a conglomerate belt and an underlying belt of amygdaloidal rock, both of which are dipping northwest under an angle of about forty-five degrees, and right under the falls the horizontal ledges of sand-rock, which constantly had been under our feet up to this place, are seen in direct contiguity with the upheaved amygdaloid ledges. The sides of the creek-bed are covered with

loose rubbish and the contact is not visible there, but in the bottom of the shallow stream the unconformity of the sandrock ledges with the trappean rock belt is so fairly exposed that no misapprehension is possible. The sandstones, instead of dipping under the amygaloid, as Dr. Wadsworth thinks, have, if they are not altogether horizontal, rather a slight inclination in an opposite direction, away from the hill, and not toward it. The sandrock ledges forming the contact differ from Keweenawan sandrocks by an almost purely quartzose composition and a light color, white and red blotched.

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

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

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

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

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

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

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

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

condition of the beds some distance off from the contact, will be found in his own forthcoming report.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The Osceola amygdaloid belt is about thirty-five feet wide; it dips in conformity with the other strata under an angle of forty degrees to the northwest; its color is reddish brown, dull, earthy; part of it is soft, porous, other parts hard, compact; its amygdules are principally filled with calcspar, delessite, prehnite and epidote; sometimes also with quartz, datolite, etc. The copper in the rock is most found in a network of fissure seams traversing the amygdaloid belt in association with calcspar, prehnite, datolite, quartz and epidote, filling the interstices between these

minerals in hackly masses of smaller or larger size; sometimes the copper is found in druse cavities in very perfect, but rather small crystals; the spar crystals of such druses usually are bright red colored, being penetrated with an abundance of minute scales of copper.

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

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

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

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

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

Under the superintendence of Capt. Daniell of the Osceola mine, the above mentioned deep shaft of the Tamarack location has been commenced in 1882 and has in the remarkably short time, up to July, 1884, reached a vertical depth of 1,550 feet.

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

At 460 feet from the surface a thin belt, only two or three feet wide, of a brownish red, very fine-grained jaspery rock occurs, which likewise carries copper. It resembles in its substance the homogeneous fine-grained pebbles of the conglomerates of the Keweenaw group. The very brittle rock is permeated in all directions by linear fissure seams filled with laumonite and calcspar or copper. Immediately beneath this belt succeeds a brecciated rock belt, forty feet thick, composed of dark brown colored, half decomposed earthy looking fragmental masses of partly compact diabase, cemented by an abundance of calcspar and laumonite seams, which are remarkably rich in copper interwoven with the sparry crystal aggregate, or also in heavy masses, many pounds in weight, imbedded between them. The foot wall of this cupriferous rock stratum is formed by a dark blackish colored fine-grained diabase belt, 170 feet thick, in its oblique intersection, which by its jointed structure, on exposure or by the stroke of a hammer, falls into small irregular sharp-edged pieces, the surfaces of which are covered with a smooth shining slickenside coating, consisting of a dark green, semi-transparent, soft, lubricous, delessite-like mineral and intermediate between these slickenside rock joints most generally a thin sheet of copper is found deposited, varying in thickness from that of the artificial leaf gold to sheets one-eighth of an inch and more

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

in thickness. The amount of copper found in this rock is larger than I have seen it in any other compact diabase rock. Under similar circumstances sheets of copper occur in the diabase forming the hanging of the Osceola amygdaloid, and in that in the hanging of the Calumet conglomerate belt. At the vertical depth of 670 feet, the shaft strikes a conglomerate belt from three to four feet in thickness, which is supposed to be the equivalent of the Allouez conglomerate; it is well impregnated with copper in coarse hackly masses, its porphyritic pebbles are soft, decomposing, and the interstitial cement is calcspar, in intermixture with chloritic mineral and laumonite; parts of the belt are also formed of a fine-grained, laminated sedimentary mud mass of deep reddish brown color, variegated by intermingled greenish colored streaks. The next lower 200 feet are almost entirely of amygdaloidal character, with a few interposed narrow seams of compact diabase. They are comparatively poor in copper. A portion of the amygdaloidal rocks is very hard, with a sort of vitreous fracture; another portion is soft and in progress of decomposition. The amygdules are mainly replenished with calcspar, laumonite, delessite and some quartz.

From the depth of 900 feet to 1,330, four rather large, compact belts of diabase alternate with three narrower amygdaloidal belts, the lowest of which is of a brecciated structure. At the depth of 1,341 to 1,357 follows an amygdaloid belt, from there to 1,409 compact diabase, then amygdaloid to 1,424, which latter carries copper and is partly a dark purplish colored earthy-looking conglomeratic mass, intersected by spar and laumonite seams, partly a very compact dark gray colored rock, with calcspar and epidote amygdules, some of it shattered and firmly recemented into a breccia by epidotic seams. From 1,424 to 1,495 compact diabase, then 15 feet of amygdaloid and from 1,510 to 1,550 a fine-grained reddish brown colored compact diabase, which was the bottom rock of the shaft on the 10th of July, 1884.

Nearly all the different compact diabase belts occurring in the shaft, in thin sections exhibit a lustre-mottled structure; the light colored areas are almost exclusively composed of transparent plagioclase crystals, intermingled with pale yellowish brown very fresh augite; in the surrounding dark colored, interstitial area, very little augite is found associated with the plagioclase, but instead of it abundant clusters of a red colored, micaceous mineral (rubellan?) associated with agglomerations of magnetite granules and with grains of olivine, of which latter the delicately laminated, micaceous mineral seems to be a paramorphic product. The red color does not seem to be essential to it, as portions showing the same laminated structure are almost colorless. Seen vertical to the cleavage, they are not dichroic, but distinctly so if the light enters parallel to it. In all of them, numerous pseudo-amygdaloidal interstitial spaces are replenished with the often before mentioned amorphous or radiated crystalline steatite-like mineral of pale or darker green color.

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

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

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

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

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

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

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

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

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

The conglomerate of the Calumet mines frequently incloses seams of a fine-grained, well laminated sandrock, exhibiting ripple marks on the surface of its layers, and locally such beds are richly impregnated with copper. Like in all the sandrocks of the Keweenaw group, the feldspar grains overbalance the quartzose grains in the rock mass. The hanging of the Calumet conglomerate is a dark colored, fine-grained diabase, which, like the above mentioned diabase belt in the Tamarack shaft, 500 feet below the surface, has a jointed structure, with the cleavage seams coated over with a soft, chlorite-like mineral in slickenside fashion, holding between themselves sheets of copper from

the thickness of tissue paper to that of a knife blade and sometimes six or eight inches square; likewise are cloudy patches in the solid mass of the diabase disseminated with an abundance of scaly molecules of copper, but the miner considers the amount of metal too small to pay any attention to its collection. In association with the compact diabase in the hanging, amygdaloidal rock masses occur, whose amygdules formed of calcspar, laumonite, quartz and delessite, often contain a considerable amount of copper.

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

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

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

On the Kearsarge location,—

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

—L. L. HUBBARD.]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

As a rule, these fissure veins were found to contain little

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

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

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

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

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

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

Three hundred and twenty-five feet south of the latter drill hole, a shaft has been sunk to the depth of 65 feet, which is supposed to intersect the second diabase belt and the third amygdaloid belt of the former drill hole. The amygdaloid is rich in small masses of copper, its vertical distance from the

jaspery seam, believed to be the Calumet conglomerate, is 532 feet, and the identity of this belt with the Osceola amygdaloid is suggested.

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

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

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

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

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

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

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

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

segregation of larger feldspar crystals within the fine-grained groundmass; the compact belts alternate with amygdaloidal seams, of which one is particularly to be mentioned as being cupriferous, the so called Ashbed of the miners. This belt is quite large, locally from 50 to 150 feet wide; in many places along the west shore north and south of Eagle River we find mines opened on it, but with the exception of the Copper Falls mine, all others are presently abandoned; the *old* Phœnix mine in former times worked in it extensively.

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

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

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

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

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

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

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

In the North Cliff mine, old Phœnix mine, Garden City mine

and Copper Falls mine, all of which are opened in the Ashbed, transverse fissure veins intersect this belt, which contribute a large share to the product of the mines.

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

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

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

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

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

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

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

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

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

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

These mineral specimens rarely come into the hands of the mining officials, and are an article of trade to which the laborers of the mine think themselves privileged. The number of travelers visiting the copper region, all desirous to gather some of these curiosities, have in the course of time caused the venders to raise their prices to fabulous height. Specimens of crystallized copper bring from five to twenty-five dollars and more, and an instance is known to me where a crystal of calcspar of the size of a hen's egg was, from the first hand, sold for eighty dollars, and the second purchaser paid ninety-five dollars for it.

East of the Central mine, along the base of the Greenstone range, a great number of old mining locations are met with which have been for a good while abandoned. All followed transverse fissure veins, and from some of them a considerable amount of copper was gained.

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

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

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

of malachite. They seem not to belong to this belt and are probably transported from a northern belt.

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

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

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

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

This conglomerate is much darker colored than the conglomerates north of it; the cement consists of trappean debris and is locally impregnated with epidote; the pebbles are also in a great measure formed of diabase and amygdaloidal rock. The porphyry pebbles are nearly all of the fine-grained, homogeneous, jaspery kind, which rock occurs in a large belt interstratified with the diabasic rocks of the Bohemian Range at Mount Houghton, and from there extending six or eight miles farther to the east without interruption. Not only rounded pebbles of this porphyry enter into the composition of this conglomerate, but a great quantity of such rock is enclosed in sharp, angular fragments, sometimes even in large blocks. The rock belt is much decayed on the surface. An efflorescence of malachite on the rock faces is frequently noticeable, but it does not contain any larger quantity of copper.

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

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

very irregular shape; also magnetite granules are sparingly scattered.

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

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

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

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

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

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

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

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

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

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

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

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

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

At times the conglomerate rock recedes from the shore and the underlying lustre-mottled diabase forms the borders of the lake; its presence is recognizable from a distance by the conspicuity

of the network of spar and laumonite seams intersecting it in all the exposures on the whole length of the shore.

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

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

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

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between the exposures of the two belts is covered with drift masses.

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

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

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

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

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

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

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

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

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

The brecciated form of these rock belts first induced me to suppose their aqueous origin, as it is hard to imagine the injection of a fire-fluid mass into the accumulated mass of small fragments, some of which are diabase fragments, without causing a fusion of them, at least partially, but as the cement differs little from the material of the felsite fragments and

incloses sharply defined feldspar crystals like they do, we must also admit that both formed in the same way.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The eastern continuation of the cupriferous conglomerate of the Delaware mine or the so called Allouez conglomerate shows itself in natural outcrops in many places on the side of the road, after it had crossed over to the south side of the range near the outlet of Mosquito Lake, which touches with its south end the north side of the Greenstone Range, and is bordered on the opposite, northern, end by a range of very conspicuous hills formed of the great conglomerate belt continued from Copper

Harbor almost without any interruption to Eagle River and farther south, retaining a width of almost a mile. This same belt is found in great width yet at the stamp mills of the Allouez mine, but farther south towards Portage Lake it is not exposed on account of deep drift deposits covering this part of the peninsula, and from the position of another belt of sandrock beds supposed to be identical with the rocks of the Nonesuch mine of the Ontonagon district and therefore positively younger than the great conglomerate, we must suppose that in the vicinity of Houghton this belt, immensely large, has shrunk to a thickness of scarcely a few hundred feet, if it is represented at all.

(5) ONTONAGON DISTRICT.

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

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

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

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

The porphyry of this belt varies in different shades of purplish brown; some portions are full of larger segregated crystals of feldspar and glassy grains of quartz; in others scarcely any quartz grains occur, while feldspar is abundant; still other portions inclose no larger crystals and are a homogeneous, fine-grained mass, with dull, conchoidal fracture. Under the microscope the groundmass is composed of a minutely granular mixture of turbid molecules which seem to be feldspar, and of a transparent, interstitial substance which is probably quartz; no really isotropic matter is between, but within this mass a large number of irregular, dark colored, impellucid granules are dispersed, which on the edges exhibit a slight permeability for the light; in addition, we find inclosed green dichroic hornblende prisms, most of them fractured or rounded on the edges, and the before mentioned larger feldspar crystals and quartz grains. A specimen of the homogeneous, fine-grained kind of

the rock, with no porphyritic segregation of feldspar crystals exhibits a truly fragmental structure, consisting of small, subangular fragments of turbid and iron-colored feldspar, of grains of quartz and of hornblende fragments cemented together. South of the porphyry belt an amygdaloid belt is exposed on the railroad, which consists of a brecciated intermixture of irregular, fragmental, amygdaloid masses cemented by abundant sedimentary interstitial seams of drab color, gritty and somewhat porous, absorbent; it has some resemblance with the Ashbed of Eagle River. Farther south a large belt of dark colored, compact diabase follows; part of it is very fine-grained like the Ashbed diabase, another part has the coarser grain of the ordinary diabases and carries olivine.

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

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

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

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

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

We learn by them that five copper-bearing, amygdaloid belts, or in the miners' language, veins, occur south of the Minnesota belt, which all have received names from the places where such a belt has been principally mined. The first belt south of the Minnesota mine is the so called Knowlton vein, worked by the

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

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

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

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

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

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

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

On the north side of the Belt location, at the distance of about

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

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

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

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

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

The porphyry belt composing the range on the north side of the valley of Cascade River apparently reposes conformably on the diabase belts forming the range on the south side. I traced

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

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

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

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

The porphyry belt trending across the north part of T. 49, R. 42, is, on its north side, succeeded by diabase and amygdaloid belts; they dip under a steep angle northwest, like the porphyry. Good exposures of these rock beds are found in the ravines of an east branch of Iron River, next to the southeast corner of Sec. 12, T. 49, R. 43. The diabase is middling fine-grained, dark blackish colored; the amygdaloids have their cavities filled with calcspar,

laumonite, delessite, prehnite, and quartz; an impregnation with copper I did not observe.

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

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

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

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

The felsitic rocks which are incumbent on this diabase belt are first met with a mile west of this promontorial point in the north part of Sec. 3, and thence uninterruptedly through Secs. 4, 5, and 6 of T. 50, R. 43. As before stated, the rock is the same brittle, compact, reddish colored, silico-feldspathic mass which composes the felsite belts of the Bohemian Range on Keweenaw Peninsula; portions of the belt have the structure of a breccia; a banded laminated structure is rarely observable in these eastern outcrops.

Thin sections of the rock appear under the microscope as a uniform microcrystalline curdled intermixture of reddish colored, somewhat turbid feldspar with interstitial quartz masses. Nearly always, dark impellucid ferruginous molecules of irregular form are found more or less copiously disseminated. In some portions of the rock, irregular dots composed exclusively of quartz grains clustered together, interrupt the homogeneity of the crystalline magma. The quartz usually incloses many microlites and air bubbles with a libelle,* capillary fissures of the quartz are sometimes infiltrated with purplish color, and here and there transparent grains clustered together are found scattered, which seem to be augite. No isotropic parts are observable except basal sections of quartz. In Sec. 4, at the base of the felsite bluffs, a fine-grained blackish colored compact diabase crops out in association with a coarse conglomeratic or brecciated mass of

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

amygdaloid blocks cemented by abundant sedimentary material of purplish brown color with dull earthy fracture, exactly like the amygdaloid breccias so frequently seen on the shore of Bête Grise Bay. Also further west in many places diabasic rocks can be seen exposed beneath the bluffs of felsite, as for instance on the north line of Sec. 7, in the fork between two creeks, where a porphyritic diabase occurs with copiously interspersed large red feldspar crystals in the minutely crystalline blackish groundmass. This rock is very similar to the porphyritic diabase which forms the hanging of the felsite of Bête Grise Bay on the north line of Sec. 35, T. 58, R. 28.

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

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

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

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

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

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

The felsite beds give occasion for a cascade about 25 feet high, above which constant exposures of the same rocks are seen in the creek bed for half a mile further on, as far as I went. Returning to the road and descending to Carp Lake, I found on the north side of the first mentioned conglomerate belt layers of compact diabase and interstratified amygdaloid seams, all dipping north under an angle of about 35 or 40 degrees. After crossing the river at the location of the old stamp mill, now destroyed by fire, we are at the foot of high vertical bluffs formed of fine-grained thinly bedded brown sandstones amounting to a belt several hundred feet in thickness. The top of the bluffs is formed by an overlying large belt of diabase interstratified with amygdaloidal seams. The upper strata of the sandstone belt on

the line of contact with the incumbent diabase are locally richly impregnated with copper, which strata were mined in connection with a transverse fissure vein intersecting the strata in this locality. The vein rock is calcspar in brecciated intermixture with fragments of the sandrock and diabase. The results of this mining were never satisfactory, and since more than 15 years, work has been abandoned there. Several other abandoned mining locations are four and five miles further west in the continuation of these high bluffs. These latter mining companies followed epidotic fissure veins charged with copper. The mining was done by driving horizontal drifts into the base of the diabase bluffs, which there sink down to a lower level in the valley than they do up at the Carp Lake mine.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(6) GOGEBIC LAKE.

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

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

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

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

CROSS-SECTIONS.

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

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

L. L. HUBBARD.

Houghton, May, 1894.

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