outcrops in which have been enumerated. Four varieties of material chiefly make up this formation, which in the order of apparent quantity are as follows:

a. A banded rock made up of alternating layers of red quartz or jasper and specular ore, designated by the miners as "*mixed ore*," the richer varieties of which are now shipped as second-class ore. See Specimens 36 and 37, State Collection, App. B, Vol. II. The contorted and plicated lamina of this rock, brought out by the alternating bright red and steely bands, and which could be but poorly illustrated in Figs. 10 ', 29, App. K. Vol. II., are very beautiful, being often contorted and plicated in a striking manner. See Iron Ores, Chapter III. It may be remarked in passing, that such contortions in the constituent lamina of rock formations generally indicate the presence of great folds in the whole formation, as is plainly the case at this locality.

On the southwest side of the basin, at points in the ore formation marked "specular conglomerate" on the map, occurs a true schistose conglomerate, in which pebbles, chiefly quartz, are bedded in a matrix of silicious ore. On the supposition that this rock may be a secondary form of the laminated or mixed ore, and from a desire not to multiply subdivisions in this connection, it will at present receive no further consideration.

b. Next to the mixed ore in quantity, so far as can be judged by what can be seen, is the pure *specular* ore. See Specimen 46, State Collection, App. B, Vol. II. The specific gravity of these specimens varied from 5.09 to 5.56, the average of four being 5.24, or greater than that of any other ore in the region, which should indicate a somewhat greater richness in metallic iron; whether furnace work will confirm this, remains to be seen.

c. The next in supposed order of quantity is a rich, black, *magnetic* ore, similar to the Spurr and Champion ores, but much coarser in its grain. See Specimen 39, State Collection, App. B, Vol. II.

d. Dividing the specular ore below, from the magnetic ore above, can be seen, in cut No. 1, Republic mine, a bed several feet in thickness of a *magnesian schist* similar to that previously mentioned, as being found in the Washington and Champion mines. See Specimen 53, State Collection, App. B, Vol. II.

XIV. The Upper Quartzite at Republic mountain is a gray massive rock, sometimes banded, and, near the contact with the iron,

sometimes conglomeritic, containing large and small flattened fragments of flaggy ore. The prevailing variety is represented by Specimen No. 50, State Collection, App. B, Vol. II.

XV. Near the south point of Smith Bay is a considerable outcrop of what appears to be a dioritic schist, not unlike Specimen 31, State Coll., containing mica and garnets. It has some resemblance, as will be seen by the description, to the micaceous clay-slate of corresponding number of the Champion section, Specimen 56, App. B, Vol. II.

The horse-shoe form of the surface rocks, as indicated by outcrops, which is so conspicuous a feature on the map, taken in connection with the dip of the strata, as indicated by the arrows and geological section, leave no doubt whatever as to the structure of Republic mountain. It is evidently the south-east end of a synclinal trough with Smith's Bay in the centre, under which, at an unknown depth, all the rocks represented would be found and in the same order. The conjectural division plane, dividing the quartzite and ore (see section), may be regarded as hypothetical, only as to its position, which of course can finally be determined by boring.

It will be observed, that where the northeast side of the horse-shoe crosses the river, there is an offset of about 250 feet to the right, and that where the southwest arm of the shoe should cross the river, but very little appearance of Huronian rocks can be discovered on the west side, the Laurentian rocks to a great extent taking their place. These facts can be best explained, by supposing a *fault* to follow the line of this portion of the river, the east being the down side. On this supposition the Huronian rocks on the west side would have been eroded to a much greater extent than on the east, leaving as a consequence the narrow and incompleted series, shown on a section through the Kloman mine.

The proximity of the Champion ore deposit to the Laurentian, it being only about 400 feet distant, while at the Keystone (three-fourths of a mile east) the distance is three or four times as far, leaving room for a greatly increased thickness of vertical brownish banded magnetic schist (see Map VII.), can be best explained, by supposing a *fault*, similar to that just described, but having a direction nearly at right angles; that is, east by south.

These two instances are the best established cases of faults on a large scale, that have come under my notice, in the whole region.

Calling to mind the series of rocks, which have been described as occurring at the Spurr, Michigamme, Champion, Keystone, Edwards, Washington, and Republic mines, we are irresistibly led to the conclusion, that they are equivalents of each other, belong to the same series, and are of the same age. This hypothesis has already been introduced and carried through the descriptions by the corresponding numbers, which have been attached to equivalent formations in each section ; it will no longer be regarded as an hypothesis, but accepted as a demonstrated theory. The Republic mountain section, it will be seen, is most complete for the rocks immediately below the iron, and the Spurr mountain section for those above. The latter embraces one formation of great extent and interest, which was not described, viz. :—XIX., which is made to include the several varieties of mica schists, so extensively developed on the south shore and among the islands of Lake Michigamme. This schist is often very silicious, and, in places, contains numerous crystals of garnets, andalusite and staurolite. See Specimen 61, State Collection, App. B, Vol. II., and Group H, Chapter III.

Near the centre of Sec. 25, at the west end of the lake, is a large mass, probably a ledge, of light-gray quartzite, which may fill in part at least, what appears to be a blank between the anthophyllitic schist XVII. and the mica schist XIX., just described. The number XVIII. is provisionally attached to this quartzite.

We have now described fifteen members of the Huronian series, from V. to XIX., both inclusive. This mica schist is the youngest member of the series, so far as my observations extend, to be found on the Upper Peninsula. It is proper to remark, however, that equivalency, member for member, of the Marquette rocks with the L'Anse, Gogebic and Menominee series, has not been established ; they are all Huronian, and it is doubtful if any are younger than XIX.

With regard to the strata below V., there is less certainty as to their order and equivalency. I believe, that the iron ore and associated rocks, to be seen at the **Magnetic, Cannon, and Chippewa** locations, belong here. They are in any event the equivalents of each other, and are very near the base of the Huronian series. See Geological Section, No. 10, map of the Marquette iron region,

which extends from the Cannon to the Chippewa. At the latter location is a considerable deposit of ferruginous, silicious schist, or lean flag ore, in which occurs, in what I understand to be an irregular pocket-like mass, a peculiar specular ore of fair percentage, greenish-gray color, and containing numerous bright facets, which resemble scales of mica. This is in comparatively low, wet ground, and the extent of the deposit has not been determined. It resembles the Gilmore ore at north side, Sec. 26, T. 47, R. 26, Cascade range, the two being unlike any other ores in the region.

About 100 tons of 55 per cent. ore was taken from the latter location several years since, but work was not continued. The Gilmore deposit, as well as the Chippewa, is nearly in contact with the Laurentian.

At the **Cannon** location is a banded jaspery rock, holding thin layers of specular ore, which bears a striking resemblance to the rock of formation XII., and even to some varieties of "mixed ore." See Specimen 16, State Collection, App. B, Vol. II. A seam, several inches thick, of pure specular ore, was found here, but did not enlarge on being followed downward. The remarkable characteristic of this schist is the fact, that on following the range northwest and southeast, mica replaces the ore, and we have a micaceous quartz schist, or mica schist depending on the quantity of the latter mineral. These facts, already noticed, possess interest in their bearing on the nature of the Felch mountain ore deposit of the Menominee region, hereafter to be considered.

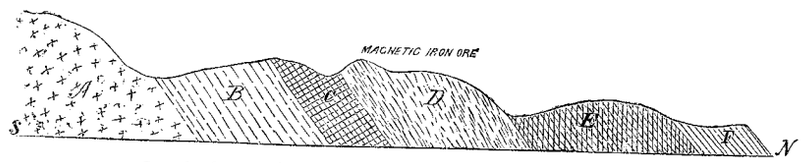
By far the most promising mine of this group, so far as existing explorations reveal, is the **Magnetic,** in south ½ of northwest ¼ of Sec. 20, T. 47, R. 30. The existence of a workable deposit of magnetic ore of medium richness has been proven. This ore, although highly magnetic, differs entirely in its character from those already described, as will be seen by inspecting Specimen No. 17 of State Collection, App. B, Vol. II. It is very hard, exceedingly fine-grained, and breaks into cubic or tabular pieces. Its structure is more like the flag ores than the first-class magnetites. It should yield about 55 per cent. in the furnace, although none has as yet been worked. The gangue is largely actinolite, instead of the more common quartz, which will help the reduction of the ore.

The relative geological position of this ore is shown in the accompanying north and south section, in connection with Map No. III.,

already referred to. As to the age of the series represented, I have but little doubt on account of their proximity to the Laurentian, and on lithological grounds, that they are the equivalents of the lowest rocks of the Republic mountain series, and are probably older than the lower quartzite V.

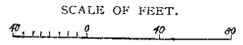
FIG. 6.

Geological Section (looking west).
Magnetic Mine. Sec. 29, T. 47, R. 30.



Level of water in Lake Michigamme 950 feet above L. S.

SCALE OF FEET.



A. Granite. B. Micaceous Quartz Schist. C. Quartzite and Quartz Schist.
D. Banded Magnetic Schist (ore). E. Greenstone or Diorite. F. Dioritic Schist.

B, C, D are undoubtedly the equivalents of the specular and micaceous schists of the Cannon series.

The line of magnetic attraction, running southwest and south, and finally south by east from the Magnetic mine, which has been traced to Sec. 9, T. 45, R. 30, is one of the longest and most persistent belts of attraction in the whole Lake Superior region. The maps of the United States Linear Surveyors mark its position very plainly, as is shown in the chapter on the Magnetism on Rocks, Plate v. Comparatively little exploration has been made on this range; but I see no reason why deposits of the character and equal in value to the magnetic, may not be found along it.

A large amount of very poor ore, and a small amount of very good ore, has been found in south part of Sec. 7 and the north part of 18, T. 47, R. 28; and quite recently a workable deposit of first-class specular ore is reported to have been found there, the locality being known as the **Michigan Mine.** Specimen No. 2, State Collection, App. B, Vol. II., is from this deposit.

Clarksburg, Geological Section No. 6, map of Marquette iron region, records the leading facts to be observed in this vicinity. The Roman numerals marked on the several formations express

their *relative* ages correctly; whether they also express the equivalency of these rocks with the Washington and other series previously described, I am not quite certain. Specimen No. 3, of State Collection, from formation marked III., possesses lithological interest, as being a Huronian rock allied to the Laurentian gneisses.

2. NEGAUNEE DISTRICT.

Following the same principle here that guided us in describing the mines of the Michigamme district—that is, beginning with those simplest in geological structure—we find on the **Saginaw and New England** range of mines (being the most westerly of this district), a structure almost identical with that of the Champion and Spurr mines. Referring to Geological Section No. 4, map of Marquette iron region, the rocks in the vicinity of the New England mine are represented as follows:—The ore formation XIII. is made up, as at the Republic mountain, of "mixed ore" (banded ore and jasper), magnesian schist and pure specular slate ore; magnetic ore being absent here, as in all the mines of this district. The quantity of specular slate ore at this mine is, so far as known, small; the small lens-shaped mass, that was formerly worked, having been abandoned.

Overlying the ore formation is the Upper Quartzite, XIV., dipping at a low angle to the north, as may be seen just north of the Parsons mine. This quartzite again comes to the surface about half a mile north, in a flat synclinal, where it again dips north and does not rise until we reach the New Excelsior mine, owned by the Iron Cliff Co., which is shown on the section.*

Returning to the **New England mine,** we find between the ore XII. and the quartzite XIV., a mass of specular conglomerate, somewhat similar to that described as existing at the Republic mountain, where it was regarded as belonging to the ore formation. The fact that it overlays the pure ore at this locality, and has lithological affinities with some of the conglomeritic varieties of the Upper quartzite, leads me to doubt in which formation it should be included. I incline to the view, that it belongs in XIV.

* This general section was constructed more than a year before ore was found at this locality, but it has not been found necessary to make any changes in it.

Formation XII., underlying the ore, is here widely different in its lithological character and economic value from the corresponding formation of the Michigamme district, where, it will be remembered, it was a valueless reddish quartz schist, containing thin lamina of iron. If we suppose tepid, alkaline waters to have permeated this formation, and to have dissolved out the greater portion of the silicious matter, leaving the iron oxide in a hydrated earthy condition, we would have the essential character exhibited by this formation as developed on the New England-Saginaw range, and as will be afterward seen at the Lake Superior mine. This is not offered so much as an hypothesis to account for the difference, as to illustrate the facts observed. The prevailing variety of rock in this formation is a brownish silicious schist, containing a considerable amount of iron (Specimen 26, State Collection, App. B., Vol. II.). Scattered through this formation are here and there large and small pockets of soft earthy hematite ore, having usually the most irregular forms, that can possibly be conceived. This subject was discussed under iron ores, Chapter III. Specimens 34 and 35, State Collection, are ores of this class.

The **Winthrop and Shenango mines** are in this formation, and are producing hematite ores as rich as any now worked in the district, and excepting perhaps the Lake Superior and McComber, richer than any other of this class, as indicated by analyses, Chapter X.

Underlying this hematite formation is a diorite, XI., similar in its general character to the rock, having a corresponding number in the Michigamme district; below this and south, are various ferruginous schists and diorites, corresponding in a general way with the Michigamme series, but which have not been carefully examined in the vicinity of the New England mine. Recent explorations afford opportunities for study, which did not exist when this section was made.

The series at the **Saginaw** and intermediate mines, as well as further west, is so near an exact duplicate of what has been given above, as to require no further mention than to state, that the deposits of specular ore are larger than at the New England, which has been mentioned as being rather small for profitable working. There has been too little work done at these new mines, to determine the extent of the deposits, but I see no reason to suppose that any of those now worked will prove very large. The fact that Sec. 16,

the Parsons and New England mines, have produced specular ores and have been abandoned, is significant. No doubt, considerable amounts of first-class ore will be taken out on this range at a profit. The only question is, whether they will continue to produce such ore in quantity for a series of years, at a fair cost for mining.

This range of ore has been traced westerly into the northeast ¼ of Sec. 24, T. 47, R. 28; west of this the drift becomes very deep and the ore range is lost. A shaft 67 feet through the sand in this vicinity found no ledge. Whether there is any stratigraphical connection between this ore formation and the Washington, six miles distant west by north, is not determined. So far as is now known, it is economically a blank in the Marquette iron belt. Work now in progress at the new Michigan mine, already noticed, may throw light on this interesting and important question. It is not at all improbable, that the Negaunee and Michigamme districts may be independent ore basins, in which case the intervening rocks, which are all Huronian, would consist of the lower members of the series, that is below XIII. Even should this be the case, valuable hematite and flag ores may be found in this now barren district.

The new **Excelsior Mine**, previously mentioned and shown on the New England section, is near the southeast corner of Sec. 6, T. 47, R. 27, and is, as will be seen, the opposite cropping of the basin. There is so much drift between these ranges, that not much can be said definitely about the nature of the intervening rocks; but it seems probable that we have here a great basin, underlaid by ore at an unknown depth, and that the New England and Excelsior deposits are related to each other in the same way, as it was assumed are the Champion and Michigamme deposits. This could be cheaply tested, and possibly an important discovery of ore made, by a drill-hole through the quartzite, near the railroad on the west side of Section 16. All efforts to find an extension of the Excelsior deposit east and west have so far failed.

Returning to the New England range and following it eastward, we find that near the south ¼ post of Section 16, it bends suddenly to the northeast, making its way diagonally across this section to the **Lake Angeline Mine**, which produces specular ore, having such admixture of jasper, as to cause it to rank intermediate in the market between first and second class ores. Whether the deposit worked at this mine belongs to bed XII. or XIII., I have not determined,

the ore partaking somewhat the character of each. The overlying rocks on the north are covered by the waters of Lake Angeline.

To the south is a high ridge of diorite, XI., on the south side of which is an extensive deposit of soft hematite, owned and worked in part by the Lake Angeline and Iron Cliff Companies.

I suppose this hematite to belong to formation X., and therefore of the same age as the Negaunee and Foster hematites, which will be fully described below. It will be borne in mind, that the hematite ores on the Saginaw range occur in formation XII.

Without attempting to point out at present the structural relations of the Lake Angeline and Lake Superior ore deposits, we will pass at once to a consideration of the latter mine, one of the most extensive, productive and geologically interesting in the Marquette region.

The accompanying map, No. IX., representing the **Lake Superior** specular and hematite workings, together with the **Barnum mine**, is intended to give the geological facts to be observed in considerable detail, as well as the condition of the workings in 1870. The structure of the east half of this mine is more complicated, than that of any other in the district, and some questions connected with it remain unsolved.

Regarding for the present the west half of the mine only, we find presented on a small scale about the same structural phenomena, which is so prominent a feature in the Republic mountain rocks. The basin, or trough, in this case, however, abruptly narrows up, the sides and bottom being as it were gathered in, as if to be tied, at a point just south of the engine-house; to the west the outcropping edges of the basin diverge rapidly, and its bottom sinks into the earth in the same degree. If we suppose the frustrum of a hollow cone, lying with its axis horizontal and its small end towards the east, to be cut in two by a horizontal plane, representing the surface of the ground, the lower half will represent my conception of the form of the Lake Superior-Barnum ore basin. Conceive now this cone to be made of sheet-lead, and to be considerably bent and dented, and the illustration will be still more applicable.

A study and comparison of sections D—D′, C—C′, B—B′, and A—A′, in connection with the plan of the mine (Map IX.) will, I think, render it plain that this conception of the structure is in accordance with the facts; although the minor folds and faults con

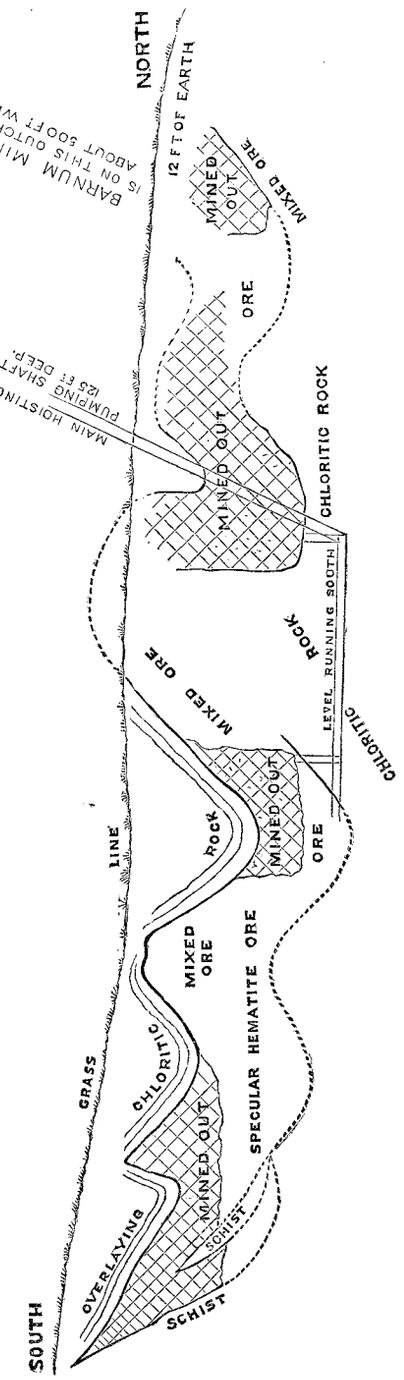


Fig. 7.—Sketch (part ideal) showing north and south section through Lake Superior mine, about 150 feet west of new engine-house, made January, 1869.

siderably obscure and confuse the general structural question. Of course, it is not absolutely proven, that the Barnum deposit dipping south, and the continuation of the main Lake Superior deposit, now worked in Pit No. 25, which dips north, are opposite croppings of the same bed, and that the intervening space is underlaid by the ore formation, and that, therefore, if work continue long enough they will eventually connect under ground; but certainly all the facts point to this conclusion. The importance of this theory in

Fig. 8.

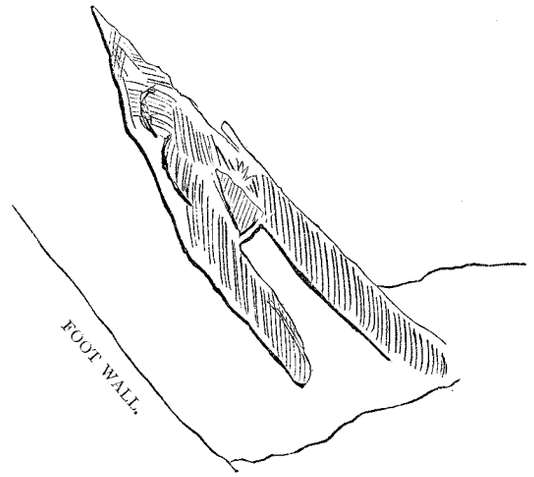


Fig. 8, represents on a large scale the south or left-hand end of the section represented in Fig. 7, and brings out the peculiar form of the "horse" of magnesian schist, which is shaded, the ore being white.

its bearing on explorations for ore, mining and valuing ore deposits, is very apparent. It shows, that such formations are not vein or dyke-line deposits, but true stratified beds, like the rocks by which they are enclosed. Their structure is therefore essentially the same as the coal, limestone, sandstone, and slate-beds, which are regarded as sedimentary deposits from water, subsequently more or less altered by heat pressure, and chemical waters acting during immense periods of time.

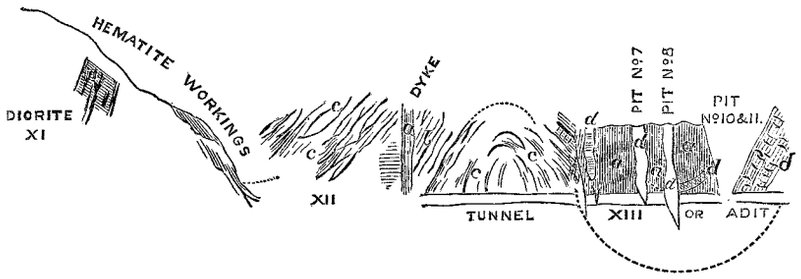
The Lake Superior-Barnum deposit evidently has a *bottom*, which will be reached within a period, of which it is worth while for the present generation to take some heed. So of many other deposits in the region.

As we go westerly from these mines the basins become, as we have seen, wider and correspondingly deeper. A depth of 300 feet in the Edwards mine reveals no essential change in the dip of the deposit, as will be seen by reference to the plans of the mine. The same is true of the Champion mine.

The time may come when, having worked out the steep upturned edges of the basins, and the flatter or deeper portions of the deposit are reached, ore properties will be valued somewhat according to the number of acres *underlaid by ore*, as coal now is.

Passing to the east portion of the Lake Superior mine, I confess myself unable to give any intelligent hypothesis of its structure. The facts observed are in part recorded on the Map of the mine on section E—E′, and on the accompanying sketch, in part ideal, which represents on a small scale a section near E—E′. There seems to

Fig. 9.—Sketch showing Geological Section of the Lake Superior mine (looking west), near Sec. E—E′, Map IX.



a. Chloritic schist. *b*. "Mixed ore." *c*. Limonitic schist (hematite rock). *d*. Pure Ore.

have been such a gathering together, crumpling, squeezing and breaking of the strata, as to nearly obliterate the stratification. An attempt has been made to represent the present condition of things, so far as revealed, by the workings. The remarkable features are the great masses of light grayish-green chloritic schist, having a vertical east and west cleavage, no discernible bedding planes, and holding small lenticular masses of specular ore, which conform in their strike and dip with this cleavage, and which seem to have no structural connection with the main deposits. They appear like dykes of ore, squeezed out of the parent mass, which we may suppose to

have been in a comparatively plastic state, when the folding took place; or they may have been small beds, contained originally in the chloritic schist, and brought to their present form and position by the same causes, which produce the cleavage in the schist. A comparison of these sections, showing effect of the folding on a large scale, with the figures (19 to 29, Vol. II.) representing the contorted lamina of the mixed ore of Republic mountain, will be found instructive. Indeed the same phenomena may be observed abundantly at the Lake Superior mine, and still better at the Cleveland knob.

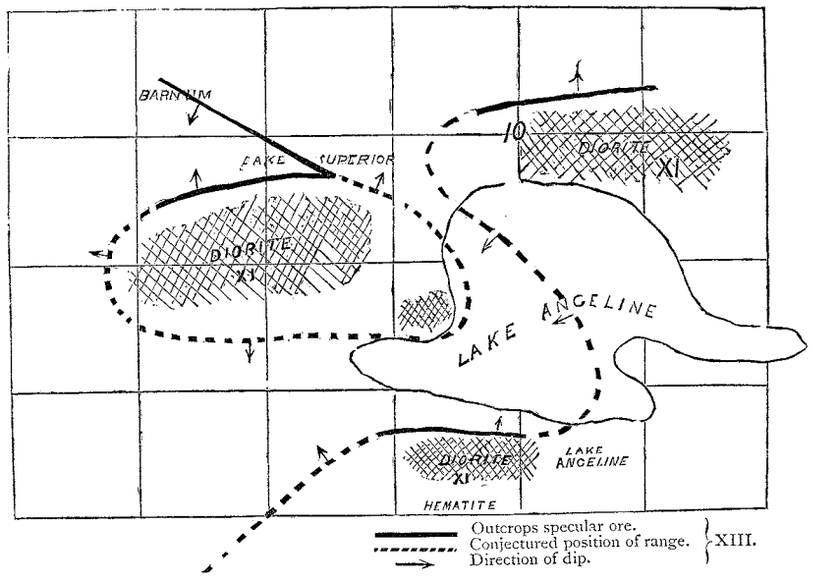
Lake Superior mine sections E—E′, and Fig. 9, may almost be said to represent a huge breccia.

The peculiar nature of the hanging wall of the Lake Superior mine deserves further notice. Instead of the quartzite, which we have hitherto found overlying all the deposits of rich ore, we have here a magnesian schist very similar to, if not identical with, that already mentioned as being associated with the ore, as will be seen by reference to the geological sections, and to Spec. 55, State Collection, App. B, Vol. II. These rocks are given, however, different colors on the maps. The hanging wall of pit No. 25, Section A—A′, it will be observed, is made up of this schist and of layers of quartzite. Whether the Upper Quartzite is replaced by this schist, making it belong to XIV., or whether it is a member of the ore formation XIII., in which case XIV. would be wanting at this locality, I am not able to determine, but incline to the first opinion.

The hematite formation XII. is fully developed at this locality, producing an excellent ore which is extensively worked. The relation of this formation to the overlying and underlying rock is obscure, as has already been pointed out. This relation was very plain, it will be remembered, on the Saginaw-New England range.

The structural hypothesis by which I have attempted to connect the Lake Superior deposit with the Lake Angeline on the south, and Marquette, Cleveland and New York mines on the east, need not be further described here, but will be understood I think, by those interested in the question, from an examination of the following figure in connection with the maps.

Fig. 10.—Sketch (part ideal) showing position of ore basins at Ishpeming.



New York, Cleveland and Marquette Mines.

The geological facts to be observed, the general structure, nature and extent of the workings of the **New York mine,** which is one of the most regular deposits in the district, are so plainly set forth on the accompanying Map, No. X., that but few words of description are necessary. It will be seen to be a monoclinal deposit, in every essential particular, like the Barnum, Champion and Spurr. Two interesting facts will be observed: 1st. The absence of formation XII.; the pure ore, with its associated chloritic schists, seems to occupy the whole space between the Upper Quartzite, XIV., and the diorite, XI. It may be here observed that, as a rule, the purest ores are found in the upper part of the ore formation, that is, nearest the Upper Quartzite; the New York mine presents an exception. 2d. The deposits on the north side of the railroad, worked by Pits No. 3 and 4, have a striking resemblance to the small deposits, Pits 16 to 21, of the Lake Superior mine, just described. The facts to be noted at the Collins location, just east, taken in connection with Pits 3 and 4 of the New York, point plainly towards the existence of a small independent trough, north of the Cleveland-New York

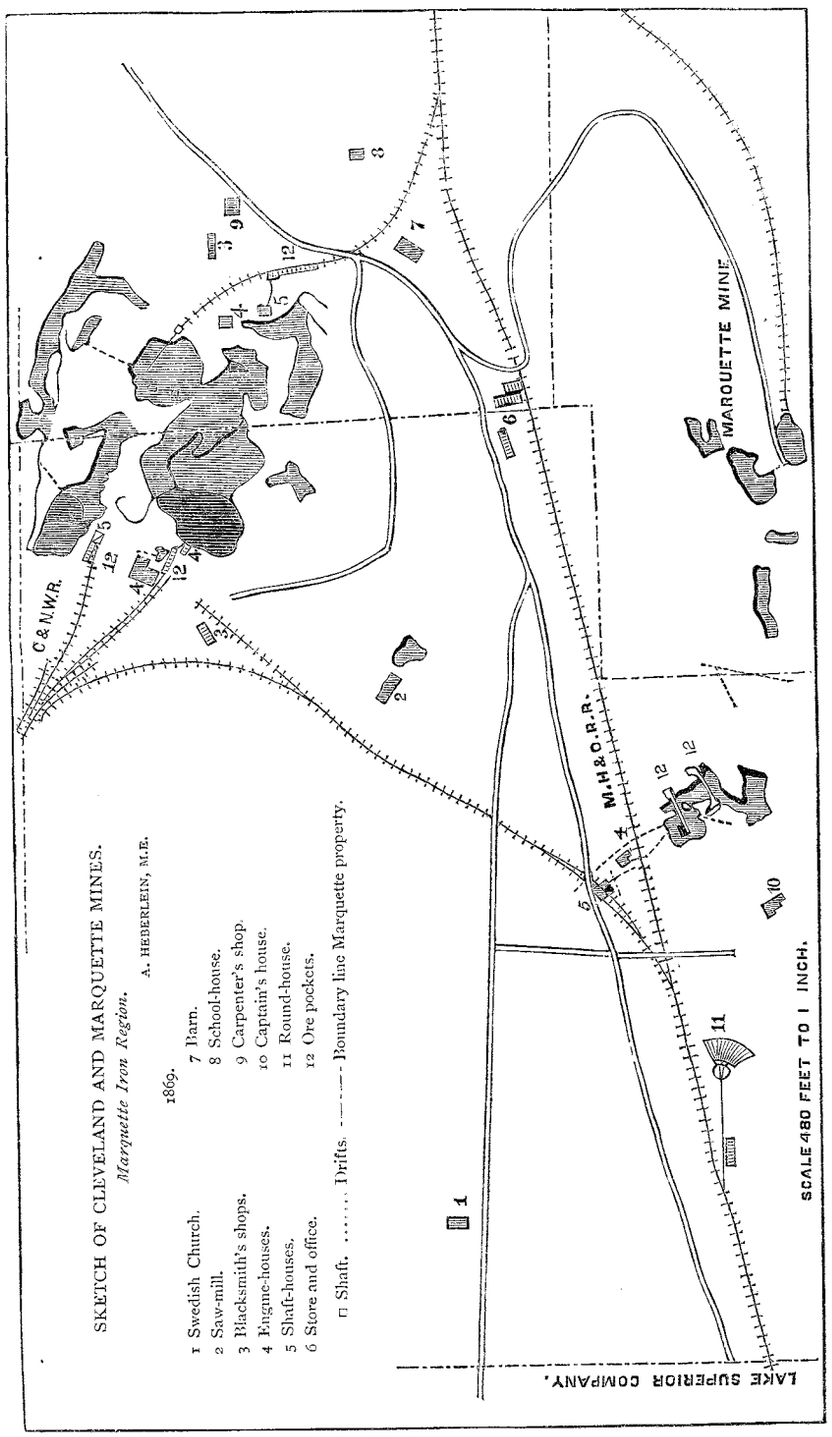
deposit. Explorations and mining operations so far, do not indicate the presence of a large amount of first-class ore here.

I made no special survey of the **Cleveland mine,** the fund at my disposal not permitting it; the main object of the survey in this direction being, to represent in detail a sufficient number of typical mines, to cover the various structural phenomena to be found in the district. The sketch of the Cleveland and Marquette mines, Plate II., from A. Heberlein's map, in connection with the New York mine (Map No. X.), will give a good general idea of this group. It will be seen, that the most northerly pit (Gents, No. 3) of the Cleveland mine, is a continuation of the New York deposit, having the same strike and dip. Gents pit is in one of the largest deposits of pure specular ore in the whole Lake Superior region. It dips south, forming the northerly edge of a narrow synclinal basin, which immediately comes to the surface again in the Swedes pit, where the ore has a northerly dip. These two pits produced in 1872 over 100,000 tons of ore. The ore basin widens and deepens to the west in a similar manner to the Lake Superior, and undoubtedly underlays the swamp, on which the village of Ishpeming is built. The connection of these deposits with those worked in the more southerly Cleveland and Marquette openings, has not received that attention which would enable me to express an opinion on the subject.

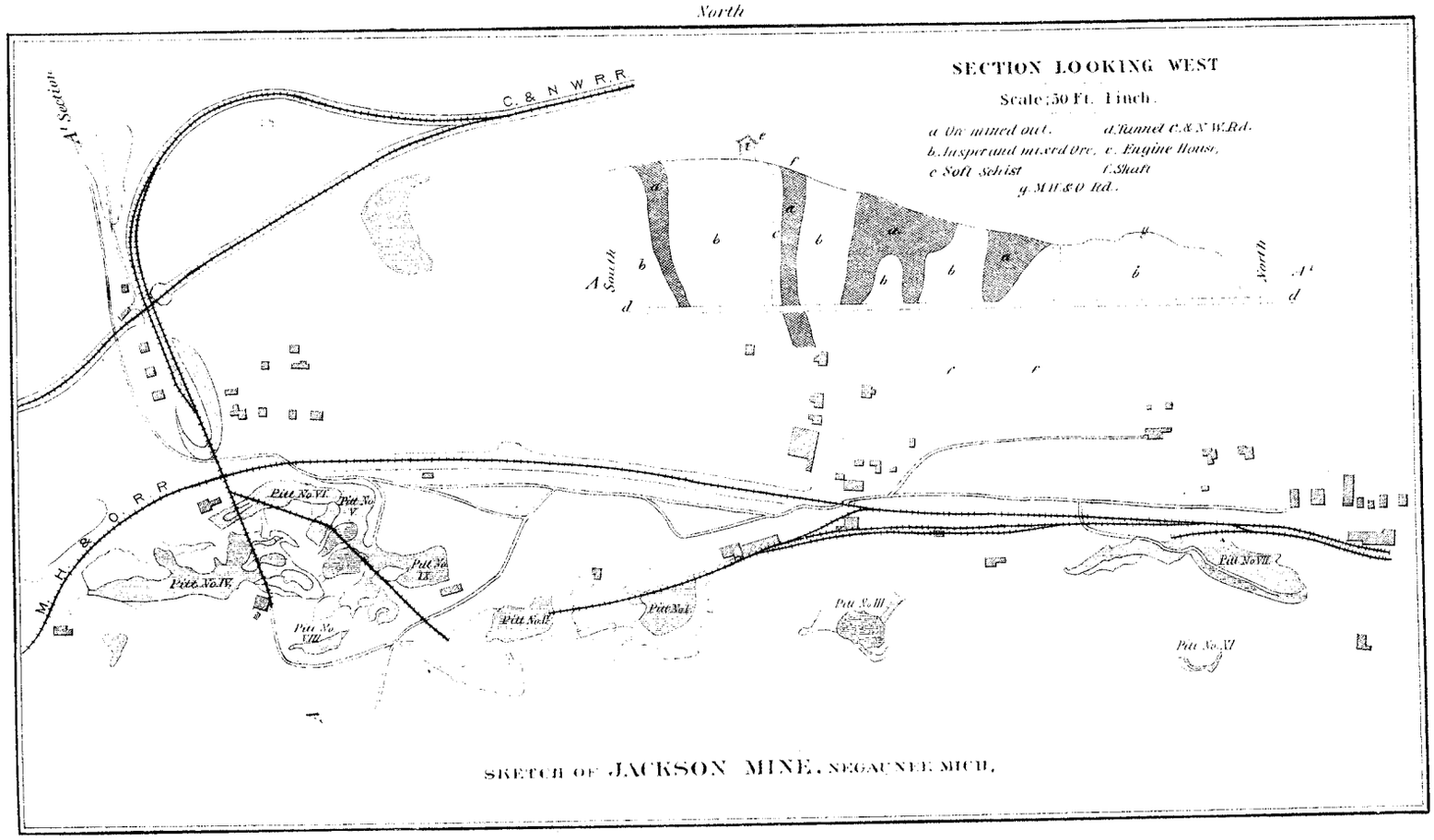
There can be little doubt, but that the Cleveland mine promises as well, if not better, for the future production of first-class specular ore, than any one of the older mines.

Jackson Mine and Negaunee Hematite Deposits.

No special survey was made of the **Jackson mine;** but the accompanying Plate (iii.), from O. Dresler's map and Atlas map of the iron Mines at Negaunee (No. V.) will make known the general structure of the mine, which is essentially similar to that of the Cleveland and Lake Superior. This mine, although it produces first-class specular ore, will be here considered in connection with the hematite deposits, because they are adjacent, and their geological structure can be most conveniently described together. The Jackson mine, so far as is known, is the extreme east end of the



North



SKETCH OF JACKSON MINE, NEGAUNEE MICH.

rich ore basin formed by bed XIII. No workable deposit of ore of any kind has been found north and east from this locality, and the ores to the south are believed to belong to a lower horizon, and to be, on the whole, inferior in quality.

Looking back over the field we have now hastily surveyed, and assisted by the map of the Marquette iron-region, it will be seen that, while there are many minor irregularities, on the whole the ore basin gradually widens towards the west, from a mere point at the Jackson mine to a width of fully five miles at the west end of Michigamme lake, beyond which too little is known, to enable us to accurately define its limits. It follows, therefore, that all the Huronian rocks north, east and south from the Jackson mine, are below, or *older than the ore formation* (XIII.) and all the rocks to the westward and inside of the ore-basin are *younger*, hence above it.

The large amount of exploration work, done in the vicinity of Negaunee, in searching for hematite within the last few years, has aided greatly to develop the geological structure of that locality. But unfortunately, the money I had to expend here was more than exhausted, before this work began, so I have been enabled only in part to avail myself of it.

The facts observed are mostly recorded on the local map, mentioned above, and on the general map of the region. By reference to the former it will be seen, that a belt of country, about one mile wide, extending southeast from the Jackson mine, is dotted over quite irregularly with hematite workings, which are mostly on lands leased from Edward Breitung, as is explained in a note on the map. These mines produce dark-colored earthy hematite, containing metallic manganese, often up to an average of 5 per cent., varying considerably in the amount of metallic iron, but on the whole averaging lower, than the hematite ores heretofore mentioned, as will be seen from the chapter on analyses. I believe these ores all belong to one formation, No. X., in which, up to this time, no merchantable ores, except the Lake Angeline hematite, have been mentioned as occurring; it is at least certain, that they are older than formation XII., which embraces the Lake Superior and Winthrop deposits.

The geological sections A—A′ through the Himrod and Green Bay mines, and B—B′ through the Jackson Company's new hematite and old specular ore workings, fully illustrate the hypothesis of

structure adopted. It will be seen, that the ore is contained between two beds of diorite, IX. below and XI. above, and that there is associated with the ore, chloritic schists and various ferruginous schists and flag ore. These last-named rocks, it will be remembered, made up this entire formation in the Michigamme district, where hematites are wanting, as are magnetic ores in the district we are describing. Underlying the lower diorite mentioned, is a clay slate, which is in turn underlaid by a gray quartzite, to be seen outcropping near the centre of the north half of Sec. 8, and represented in Sec. A--A′ under the number VIII. This is undoubtedly the same quartzite to be seen in the railway cut near the northwest end of Goose lake, where it is overlayed by a soft schist. See formations VIII. and XI., Geological Sec. No. 1, Map III. The clay slate on south shore and near west end of Teal lake, and exposed in railroad cut one mile east of Negaunee, is also believed to be of the same age.

The lithological character of the several formations, mentioned above, will be better understood by an examination of the following specimens of the State Collection: No. 21 quartzite from VIII.; No. 20 is a clay slate also from VIII.; No. 31 is from diorite IX.; Nos. 24 and 25 are hematite ores from formation X.; No. 26 is a specimen of ferruginous silicious schist from the Foster mine, which is also regarded as belonging to the same formation (X.); Specimen 28, from the same formation, is a magnetic, chloritic, silicious schist.

Referring again to Map No. V., it will be observed, that the Jackson Company's hematite workings, the McComber, Maas and Lonstorf's most northwesterly opening, the Rolling Mill, Himrod, Spurr and Calhoun, and Iron Cliff Co.'s Sec. 18 mines, are all in a rude curve, skirting the great development of diorite, which seems to limit these deposits on the southwest, and under which they all dip. The remaining openings are mostly contained in a narrow belt, which extends east-southeast from the Grand Central, diverging from the other range, which curves to the south. The diorite ridge which runs through the centre of the latter range is apparently a synclinal ridge underlaid by ore, which should therefore dip towards it from all directions, as is the fact so far as known. Undulations in the bed now unknown, may very likely bring the ore to the surface at several other points.

There can be no doubt of the great extent of this ore; it certainly can be on the average more cheaply mined and shipped than any other ore in the region, except perhaps the hematites of the Taylor and S. C. Smith mines. Location at the junction of two railroads, and contiguity to a prosperous village, are additional advantages, which will go a long way towards offsetting the disadvantages of lower percentage. The presence of several per cent. of manganese in this ore helps its working in the furnace, rendering it a desirable mixture. The McComber mine was first opened, and its ore is well and favorably known to many furnacemen. My analyses indicate, that this is a richer ore than the other mines of this group, but this cannot be established without further developments, as work has but just begun at most of them.

The **Teal Lake** ore deposit belongs to the same formation, as may be seen by an inspection of the map and sections. I have not been able, however, to find any good hematite in the old exploration pits, now nearly filled; a lean flag ore is very abundant.

The **Foster mine,** near southwest corner of Sec. 23, T. 47, R. 27, is another hematite deposit belonging to formation X. It has produced a considerable amount of hematite ore of medium grade, which contains no manganese; the deposits, or rather pockets, are pre-eminently irregular in form and uncertain in extent. The geological position of the Foster range is shown on Map No. III. and accompanying sections.

The Cascade Range.—The deposits on this range are the only ones now wrought, which remain to be described in the Marquette region. Like nearly every other described in this report, this ore was known to the United States linear surveyors, and afterwards examined and commented upon in considerable detail by Foster and Whitney. The range extends east and west through the south part of T. 47, R. 26. See Map III. The locality known as the **Gilmore mine,** at ¼ post between sections 23 and 26, is the most easterly point at which ore has been seen in quantity. This, it will be observed, is about three and one-half miles east, and two miles south, of the Negaunee hematite mines. The range has been traced west by south from this place for five miles, or to a point just four and one-half miles south of the Jackson mines. This country has recently been opened up by a branch of the C. and N. W. road, which closely follows the ore range. The principal open-

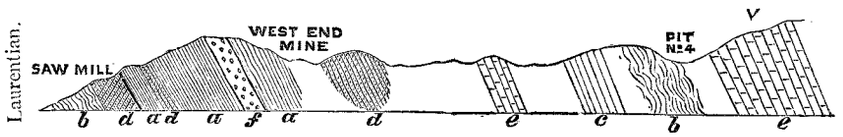
ings have been made by the **Cascade, Pittsburg and Lake Superior, Carr and Gribben** Iron companies, who shipped an aggregate, in 1872, of over 40,000 tons, nearly all of which was by the first-named company and its lessees. The last two named companies —Carr and Gribben—have done too little work, to enable us to speak with much certainty about their deposits. (See tables, on Sheets XII. and XIII., Atlas.) By reference to the chapter on analyses, which is quite full regarding these ores, it will be seen that they have, on the average, less metallic iron and more silica, than the standard hard ores of the district. The West-End mine, however, worked by the Cascade company, and which produced last year about one-third of their product, appears to be an exception to the above rule, and to rank nearly with the first-class specular ores ; certainly considerable amount of high grade ore was taken from this pit last year, but whether it was kept separate from the leaner varieties in the shipments I do not know. The ore which largely prevails is a silicious or quartzose, or jaspery (practically these words have the same import) red oxide, having a characteristic coarse, slaty, or *flaggy* structure ; hence the name by which they are known throughout this report. They correspond nearly in composition, although not in their appearance and geological position, with the second-class ores of the old mines, as the analyses referred to prove. See Iron Ores, Chap. III. Some varieties closely resemble, if they are not identical with, certain varieties of the high grade ores ; but as a rule they are lighter in weight, duller in color and lustre, are harder under the knife, and pre-eminently flaggy or slaty in structure. I have not been able to obtain a statement of the working of these ores in the furnace. Further information regarding their lithological character may be obtained from descriptions of Specimens 5 and 6 of the State Collection, App. B, Vol. II. ; the latter is the beautiful "Bird's-eye" slate ore from the Bagaley and Wilcox pit. Specimen 7 is from the diorite bed, which overlays the West-end mine, and is interesting from its resemblance to granite in outcrop. *

The structural position which these ores seem to me to occupy is shown on geological section No. 2 of Map No. III. They are near the Laurentian, and the whole series is overlaid by a talcy quartzite, which I believe to be the equivalent of No. V. of the Re-

* Mr. Julien has determined the feldspar in this rare variety to be orthoclase.

public mountain series, and to be the same bed, which outcrops so conspicuously on the north side of Teal lake, and is calcareous at the Morgan furnace and at the Chocolate flux quarry, where it strikes the shore of Lake Superior. This rock varies more widely in its lithological character, than any other in the region, as will be pointed out elsewhere. If this hypothesis is correct, it will follow, that these ores are the equivalents of the Michigan and Magnetic ores of the Michigamme district, and are older than any iron bed made out in the Republic mountain series. The fact, that no iron in quantity has been found north of Teal and Deer lakes under quartzite V., where we should expect to find the opposite cropping of the Cascade series, is to be regarded in considering this question. The shortness of this range, which appears to terminate abruptly to the west, has not been found far east, and has altogether a local and isolated character, is significant. A hasty examination will satisfy any one that the *quantity* of ore in these deposits is very great, and that it is very favorably situated for mining and transporting. The accompanying north and south sec-

Fig. 11.—Geological section across Cascade range, looking west.—Part Ideal.



a. Flag ore or silicious hematite schist, in places quite rich. *b*. Banded jasper and specular ore with flag ore. *c*. Hematite rock or hematitic silicious schist. *d*. Diorite and dioritic schist. *e*. Quartzite. *f*. Conglomeritic and brecciated quartzite.

tion represents the different rocks to be seen outcropping on this range, projected on one plane. No attempt has been made to group them under formations I. to IV., to which they are supposed to belong. The general section No. 2, Map III., which has been mentioned, should be examined in connection with this sketch.

The **Iron Mountain, Ogden and Tilden** mines, not now worked, produced flag ores similar to those of the Cascade range, but not so rich on the average. These deposits belong, as will be seen by Map No. III., to formation X.; the Iron Mountain and Tilden mines being in opposite croppings of the same basin. The **Foster mine**, as has been observed, is also in the same formation, being overlaid and underlaid by flag ores. The Negau-

nee hematite and Teal lake ores being also in X., make that formation remarkably fruitful in the quantity and variety of ore, which it contains; but it does not, so far as known, hold the high grade specular ores in quantity.

Lower Quartzite, embracing Marble and Novaculite.

A brief consideration of the question of materials for *furnace flux* may come within the limits determined for this report. The subject, so far as the Silurian limestones are concerned, has been fully considered by Dr. Rominger, in Part III., who gives many analyses. The Menominee marbles will be mentioned in Chapter V. on that region. No calcareous, or other rock suitable for flux, has yet been found in the Laurentian system of the Upper Peninsula, although in Canada large beds of marble occur in this oldest series. It remains only for us to consider the silicious variegated marbles, found in the eastern part of the Marquette region, none having been worked west of Goose lake, which happens to mark the most easterly show of iron. The purest stone is found at the Morgan furnace, seven miles west of Marquette, where a heavy east and west bed of silicious marble, with vertical dip, and having associated with it clay slates, is prominently exposed. The prevailing colors are light-gray and pink. Specimens 11 and 12, State Collection, are from this locality; and Specimen 70, from the Gorge, represents the chloritic schist, which underlies the marble on the north.

The Chocolate Flux quarry on the shore of Lake Superior, three miles south of Marquette, is another locality, from which a small amount of furnace flux has been obtained. But the admixture of quartzose matter is here so great, that its use has been abandoned. Specimens 9 and 10, State Collection, represent the so-called "marble" and slate from this locality. It and the associated rocks are fully described in the extract from Dr. Houghton's unpublished notes, given in Appendix E, to which a sketch is appended. Mr. Julien examined a full suite of specimens from this locality, which are described in App. A, Vol. II., Nos. 106 to 113. No other marble locality possesses sufficient interest, to warrant mention, although flux has been quarried at several points near

Goose lake. It has been mentioned that the *novaculite* quarry, just east of Teal lake, from which whetstones were taken more than twenty years ago, is in the same formation. These stones are not now worked. See Specimen 13, State Collection, App. B, Vol. II.

During the past season several car-loads of quartzite were quarried in the same vicinity, and used as lining for Bessemer steel converters, at Capt. E. B. Ward's works, for which purpose it answered well.

The various marbles, slates, and quartzose rocks described above, are all believed to belong to one and the same formation, the Lower Quartzite (No. V.), which, it will be remembered, underlies the Republic mountain series, and overlies the Cascade series. This formation is one of the most interesting, geologically, in the Marquette region, and is worthy of a far more careful study than I have been able to give it. Specimens 8 to 13, inclusive, State Collection, App. B, Vol. II., represent several varieties of rock from this formation; as many more varieties could easily be procured, including some very fair specimens of iron ore from south and east of Goose lake.

A brief description, in addition to what has already been given, of the great geological basin formed by this quartzite, which embraces within its folds the great mass of the Huronian rocks, and nineteen-twentieths of all the ore, will possess interest. Like the ore horizon XIII., which we saw came to a point at the Jackson mine, and widened to the west, so the opposite croppings of this quartzite converge to the east and come together at the Chocolate Flux quarry, already described. From this starting-point the *south rim* of the basin bears away towards Goose lake, where some minor folds and low dips make it the surface rock for a large area northeast of the lake. From the south end of the Lake west, the formation has a prevailing talcky character, often argillaceous and sometimes conglomeritic; it has a great thickness and strikes west by south. West of the Cascade it seems to assume more the character of a chloritic gneiss and protogine, or at least a well-defined bed of protogine rock occupies the position in which we would expect to find the quartzite. See Map No. III. and sections.

The *northerly rim*, starting also from the Chocolate quarry, maintains a nearly due west course, crossing the railroad at the

Morgan furnace (where it holds the maximum amount of lime), forms the barrier rock in the Carp at the Old Jackson forge, passes north of Teal lake and south of Deer lake, occasionally at various points further west, and last, so far as I know, north of the Spurr mountain, nearly 40 miles west of Lake Superior.

3. Escanaba District.

The most southeasterly deposit in the Marquette region, and one which is entirely isolated from the localites already described, is the **S. C. Smith Mine**, producing soft hematite ore; it is located on Sects. 17, 18, and 20, T. 45, R. 25, and connected by a branch with the C. and N. W. railroad. It is but 42 miles from Escanaba, giving it a great advantage in distance over any mine, now shipping ore through that port. The geographical position is less remarkable than what might be called its geological isolation, for it appears to be in a small patch of Huronian rocks, in the midst of a great area of barren territory, underlaid by the Laurentian and Silurian systems. See Map III. The discovery of this deposit, a few years since, by Silas C. Smith, Esq., reflects great credit on his knowledge of the nature and distribution of ore deposits, and his perseverance in searching for them. Mr. Smith also first directed attention to the Republic mountain, which was, until within a few years, called by his name; he also made the first explorations in the Menominee region.

The few outcrops about the S. C. Smith mine, and the small amount of work done, when my examinations were made, enable me to say very little about its geological structure. The ore range runs northwest and southeast, approximately parallel with the Escanaba river, and cuts the southwest corner of Sect. 17. Contiguous on the northeast (whether underlying or overlying I am unable to say) is a bed of black clay-slate, in places identical with the so-called "plumbago" of the L'Anse range, which has been heretofore considered. Numerous fragments of a similar slate, probably belonging to the same formation, are found on the east side of Sec. 29. Laurentian granite is seen on both sides of the river, just east of this locality, away from which we have a right to assume the slate dips, rendering it probable, that the whole series dips

southwesterly, in which case the slate would form the foot-wall of the ore deposit, as on the L'Anse range. On Section 20, west of the river, a talcky schist, holding grains of quartz, was observed, but its relations with the other rocks were not determined.

Near the west ¼ post of Section 20, and at other points in the vicinity, a flag-ore of good quality has been found; a specimen from one of the test-pits gave Mr. Britton 56 per cent. of metallic iron; whether there is any considerable amount of ore of this degree of richness has not, I think, been determined. Hand specimens of very fair specular ore could be found, but, as a whole, it seemed to me to be much more closely allied to the flag ores. Small boulders of this kind of ore had been found in this vicinity by C. E. Brotherton, some years ago.

Lapping over the upturned edges of the black slate on Sec. 17, and extending towards the east, is a horizontal Silurian limestone, which is, however, cut off by the river, beyond which numerous outcrops of granite and gneiss rear their heads above the flat sand plain. Silurian rocks are also seen on parts of Sec. 19, but west and northwest the country is all Laurentian, so far as I have been able to learn. South and east is a great plain, undoubtedly underlaid by Silurian rocks, but affording no outcrops, except near Little lake, where an isolated hill, apparently Huronian, rises out of the plain; I have not learned that any indications of iron have been found there.

I regret not having had the time and means to make a re-examination of this interesting and important district, after last season's extensive developments, and reluctantly present this imperfect sketch for want of fuller and more complete data.

4. L'Anse District. (See Plate IV.)

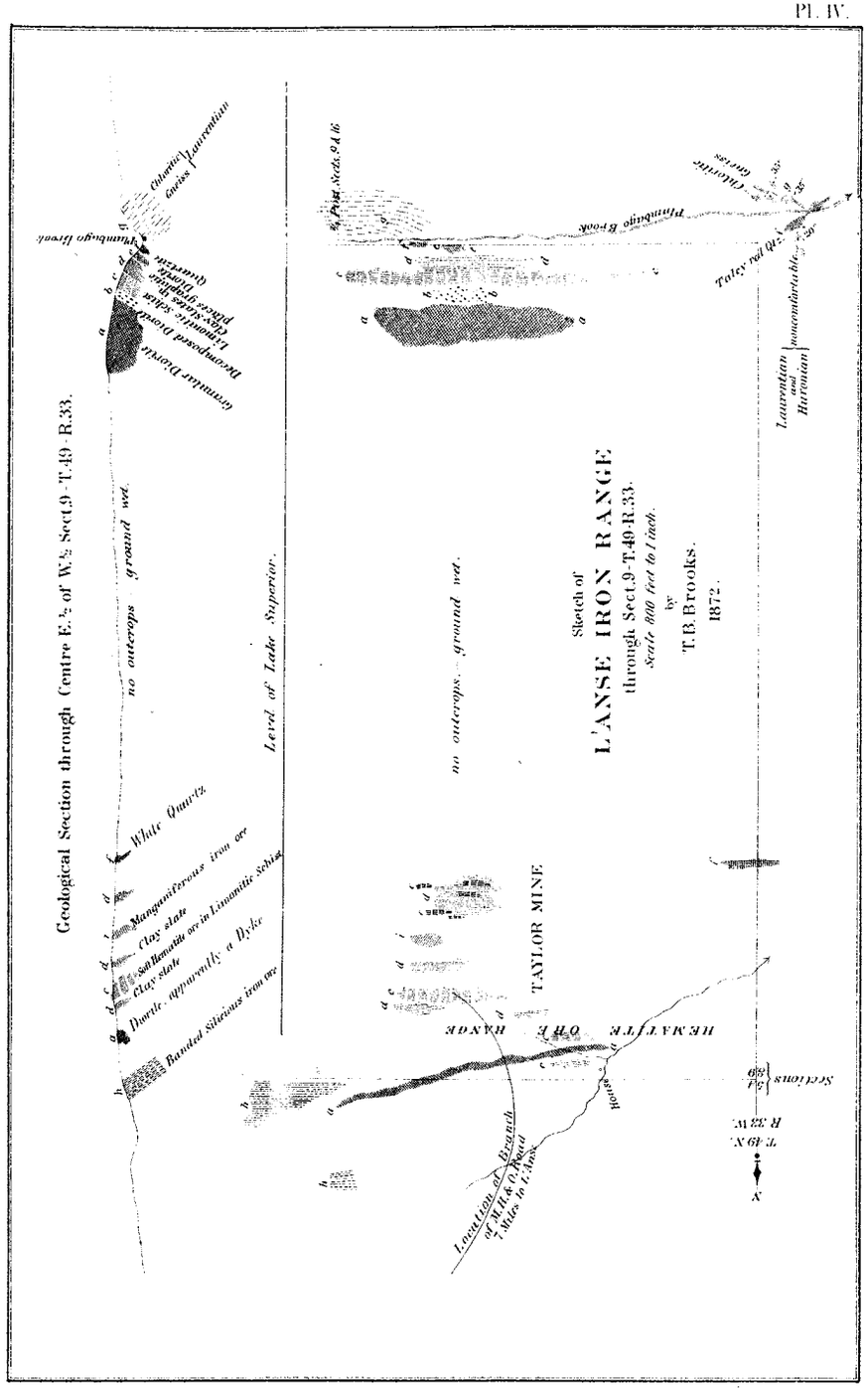
The United States surveyors marked "iron ore" in two places on the line between Sects. 4 and 9, T. 49, R. 33. A quartzose or silicious brown and red ore can be seen outcropping, at several points in this vicinity. These facts early drew the attention of explorers to this district, and a considerable amount of land was bought from the government, for iron, as early as 1864. The fine harbor at the head of Keweenaw bay, only seven miles distant, and the abundance of excellent hard wood, tributary to this bay, have long

caused it to be regarded as one of the best points in the northwest, at which to make charcoal pig-iron, and establish other manufactories related thereto. The soil along the protected shores of Keweenaw bay is good, which led to the establishment of Indian missions there many years ago. A circle having the village of L'Anse as a centre, and a radius of 35 miles, would embrace the Washington, Edwards, Champion, Republic, Michigamme, Spurr Mountain, Magnetic and Taylor mines, with others less promising, together with all the copper mines in the Portage Lake district, the Hecla-Calumet mine, as also the principal mines in the Ontonagon district. It would also embrace all the roofing slate territory to which attention has already been directed, and an immense sandstone area, about which little is known. The amount of hard wood within the circle would be surpassed by very few equal areas on the Upper Peninsula, and the quantity of pine is large. A railroad running west, tapping the Ontonagon copper region, and continuing through the Gogebic and Montreal river mineral region, so as to connect with the Northern Pacific road, would, with existing roads and the excellent water communication, make the greater part of the area described easily accessible from L'Anse. If the advantages of the geographical position of L'Anse have not been here overstated, it is somewhat remarkable that the locality should have remained so long undeveloped. The want of railroad communication with the outside world was, undoubtedly, the main reason. What effect the very heavy grades, encountered within ten miles of the town, will have on the amount of ore which will be carried there from the Michigamme district, remains to be seen. The ore from the Taylor mine, and others that may be opened on the L'Anse range, can be put on board vessel at L'Anse at less cost for transportation, than any equally good ores with which I am acquainted, on the entire chain of the Great Lakes.

As has been before remarked, the L'Anse iron range, so far as made out, lies in the north part of T. 49, R. 33, the best ore being in Secs. 9, 8, 4, and 5; it has a general easterly and westerly trend, like nearly all of the iron ranges of the Upper Peninsula.

The **Taylor Mine,** the only point where the existence of a workable deposit has been demonstrated by actual exploration, is near the centre of the northeast ¼ of northwest ¼ Sec. 9, T. 49, R. 33.

Pl. IV.



This ore deposit is 950 feet above the surface of Lake Superior, and seven miles from L'Anse by railroad, built or building. The ground slopes gently to the west, affording an excellent opportunity for attacking the ore, which is covered by but a few feet of earth. The timber in the vicinity is first-rate hard wood.

The prevailing variety of ore at the Taylor mine is a soft hematite, similar in character to that of the Lake Superior and Winthrop mines. A number of analyses of average specimens, the results of which are given in full in Chapter X., varied from 44 to 57 per cent. metallic iron, with a remarkably small percentage of silica for an ore of this class. I see no reason to doubt but that a hematite can be mined here, which will yield an average of 55 per cent. of pig-metal in the furnace. Cross trenches and drifts show the deposit to have a maximum thickness 20 to 25 feet free from rock, and three or four times this thickness of such mixtures of ore and rock, as usually occur at hematite mines. The distance between the most easterly and westerly points at which ore has been found, is about 1,000 feet, but up to this time the explorations made have not demonstrated the deposit workable, as to quantity and quality, for more than about one-fourth of this distance. The oft-mentioned irregular pocket-like character of these deposits makes it difficult to predict, with any degree of certainty, regarding them, beyond what can be actually seen. But the heavy bed of hematitic rocks, which show a constant tendency by their decomposition to pass into ore, together with what has been actually developed by the workings, leaves no reasonable doubt but what there is here a large workable deposit of ore.

About 200 feet south of this ore deposit, and overlying it (the whole series dip south), is a bed of highly manganiferous iron ore, average specimens of which have yielded as much as 44 per cent. of the oxide of manganese; such ore must, of course, be comparatively poor in iron; this subject was considered under iron ores in Chapter III. The deposit is of uniform quality for a thickness of ten feet, and was penetrated by a shaft for the same distance. One per cent. of oxide of manganese was reported in some of the analyses of soft hematite mentioned above, showing the general dissemination of this substance, which seems to have its greatest concentration at the point we are describing. Whether this ore would possess value in the manufacture of metallic manganese, I am not

able to say, but its presence, undoubtedly, gives additional value to iron ores, in improving the quality of the metal produced, and causing the ore to work more easily in the furnace, besides especially adapting the metal for steel manufacture.

Several other "shows" of iron in this vicinity are worth mentioning. Near the south ¼ post of Sec. 4, being on the north face of a high hill, is an extensive outcrop of several varieties of flag ore, more or less mixed with rock, in the vicinity of which considerable exploration work has been done. Some rich hand specimens of specular ore have been procured at this locality, but the great mass of the material to be seen is made up of layers of silicious ore, banded with quartzose material, the latter greatly predominating. The indications of hematite to be seen here are not promising. I see no reason why a flag ore yielding from 40 to 50 per cent., may not be sought for with reasonable chances of success. A similar ore was found several hundred feet farther north. The quantity of this mixed material existing in the S. ½ of S. ½ Sect. 4 is undoubtedly very great.

In the S. ½ of the N. E. ¼ of Sect. 8 are outcrops of hematitic rocks, which point towards the continuation of the Taylor mine series, making this a promising ground for exploration. Further west and southwest the ground falls off, the drift deepens, and no outcrops of any rock, so far as I know, are to be found, except in the immediate valley of Plumbago brook, where in Sect. 13, Town 49, R. 34, is an outcrop of argellite, which suggests a possibility of there being roofing-slate in the vicinity. Three miles west of the Taylor mine is the east edge of a treeless, sandy plain, which occupies nearly the whole of T. 49, R. 34, and extends into the townships south and west.

A similar desert country is passed through by the Peninsula Railway, commencing 7 miles from Negaunee. This latter, however, is underlaid chiefly by Silurian rocks, while the other is believed to be Huronian.

On the south side of Sect. 9, between Plumbago brook and the diorite ridge, which extends easterly and westerly more than one-half way across T. 49, R. 33, is a range of hematitic rock, similar to that at the Taylor mine, but which is not so promising for ore, so far as explorations have revealed. It has been traced for a distance of more than half a mile, and is the rock which immediately underlies the diorite, being itself in turn underlaid by clay-slate, the whole series dipping to the north, as will be seen on Plate IV.

Before dismissing the economic consideration of this district, it would be proper to notice the so-called "plumbago," found so abundantly in the north bank of Plumbago brook; but as this subject has been fully treated under the head of Carbonaceous Shale, Chap. III., it need not be further referred to here.

The **Huron bay slates** with associated rocks, may be regarded as belonging to the L'Anse series, although more than ten miles away in a northeasterly direction.

This district, which is now being explored for roofing-slate, affords indications of iron at several points, which I have not had such opportunity to examine, as would enable me to make any definite statement about them. So far as I can learn, those best acquainted in the district are not sanguine as to the existence of workable deposits of merchantable ore. At the end of Chap. I. will be found brief statements, regarding the slate companies now at work in this little-known district.

An inspection of Plate IV., in connection with what has been said, makes it necessary to add very little, regarding the structure of this range. The absence of outcrops through the central portion of Sec. 9, leaves the geological section quite incomplete. There can be little doubt, however, but that the quartzites, diorites, clay-slates and hematitic schists, so well exposed on the north side of Plumbago brook, where they dip north, are the equivalents of the Taylor mine series, which dip south, although the sequence is not exactly the same; and the diorite, so conspicuous on the south rim, is not exposed on the north side of the basin, unless the dyke-like mass of greenstone north of the Taylor mine represents it, which I do not think probable. The absence of outcrops also makes it impossible to determine whether there are any minor folds between the two croppings of the basin. If there are no such folds, then there is room for a considerable series of rocks above or younger, than those enumerated; and among them should occur, if it exists here at all, the rich hard ore of the Marquette district. It is assumed in this hypothesis, that the rocks to be seen are the equivalents of formations I. to X. of the Marquette series; this assumption is based chiefly on lithological grounds. Any rich hard ores found must be specular or red oxides, as there

is an entire absence of magnetic attraction in the L'Anse district. Magnetic ores have not as yet been found associated with soft hematites, so far as I am aware, in the Upper Peninsula.

The diorite immediately north of the Taylor mine has been mentioned as *dyke-like*. Whether it actually cuts the series of clay and ferruginous slates and schists at an acute angle, was not determined, but in places it certainly has that appearance. If it does so, it is the only case that has come under my observation, in which the Huronian diorites (often termed greenstones and traps) do not conform with the schistose and slaty strata, with which they are associated. This locality, in connection with others which show *unmistakable dykes* of magnesian *schist* cutting various rocks, is worth the study of the geologist, but is comparatively not of much importance to the explorer and miner. Mr. Julien, as will be seen by reference to App. A, Vol. II., Specs. 342 to 353, regards the L'Anse greenstones as a peculiar variety of diorite.

Another point of considerable interest, in connection with the diorites of this locality, is the *dioritic sand*, which forms the base of the great south bed, and separates it from the underlying hematitic schist on the south. This material is an angular, coarse, dark, greenish sand, and has evidently been produced by the disintegration of the rock, which is in places quite friable.

But by far the most interesting geological fact to be observed at this locality, and one, the importance of which can scarcely be overestimated in considering the grand subdivisions of the Azoic rocks, is the *nonconformability* of the Huronian, or iron-bearing series, with the older Laurentian, which can be observed in the gorge formed by Plumbago brook, about 400 feet southwest of the southwest corner of Sec. 9, T. 49, R. 33 (See Plate IV.). Here a talcky, red, quartzose rock, dipping at a low angle northwest, and which is unmistakably Huronian, is seen nearly in contact with a Laurentian chloritic gneiss, which dips at an angle of about 35° south-southwest. The same phenomena can be noted at a point near the Republic mountain (see page 126); and the nonconformability is further proven by the fact that the Laurentian generally abounds in dykes of granite and diorite, which are almost entirely absent from the Huronian.

CHAPTER V.

MENOMINEE IRON REGION.*

THE centre of this region is about 40 miles west by north from Escanaba, 50 miles south-west from Marquette, and 50 miles north from Menominee, as the bird flies. (See Map, No. II.) The area known to bear iron is embraced within a square of 16 miles, being portions of Towns 39, 40, 41 and 42, Ranges 28, 29, 30 and 31. This does not include the iron deposits west of the Paint river, nor the Michigamme mountain, owned by the Republic Iron Co., in Sect. 4, T. 43, R. 31.† The iron ores in the Menominee region occur in two approximately parallel E. and W. *belts*, each probably composed of two distinct *ranges* or horizons of ore; these belts are separated by a broad granite area, in which a little unpromising iron has been found on Sects. 10 and 15, T. 41, R. 29.

This granite area narrows towards the west, caused by the convergence of the iron belts, and has nearly the shape of a flat-iron. The region is drained by the Menominee river, which skirts its W. and S. sides, and by the Sturgeon, a branch of the Menominee, which winds through the eastern part of the iron-fields.

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* The facts contained in this chapter, as well as on Map No. IV. of Atlas, are largely from the Surveys and Explorations of Prof. R. Pumpelly and his assistant, Dr. H. Credner, made for the Portage Lake and Lake Superior Ship Canal Co. Prof. Pumpelly placed his private notes and sketches at my disposal, and added most valuable explanations. A valuable paper on this region is "The pre-Silurian formation of the Upper Peninsula of Michigan, in North America, by Dr. Herman Credner, Leipsic, illustrated by maps, diagrams and geological sections found in Plates VIII. to XII. (from the Journal of the German Geological Society)." Prof. Pumpelly and Dr. Credner are not in any way responsible for the hypothesis of structure here employed, nor for the views expressed as to the quality of the ores.

† A large amount of silicious iron ore occurs at this locality on the S.W. side of a high hill. Marble is found south and west, but in greatest abundance to the north, between Deer and Fence rivers, and on the upper waters of those streams. This district possesses much geological interest, and quite possibly economic importance, but means were not available for its examination.

1. South Iron Belt.

The South and, geologically, uppermost iron range of this Belt is probably the most regular and one of the most extensive iron deposits on the Upper Peninsula. The most easterly exposure of ore in this range is at the Breen mine on N. ½ of N. W. ¼ of Sec. 22, T. 39, R. 28. This location is 34 miles from Escanaba, and 45 miles from Menominee, in a bee line. The air-line distance from the elbow of the C. & N. W. R. R., now in operation, is 12½ miles.

Travelling from the Breen mine on a course N. 74° W., which is parallel with the general course of the river, we find on S. ½ of Sects. 11 and 10, N. ½ of Sect. 9, and S. ½ of Sect. 6, T. 39, R. 29, large natural exposures of ore, which have been still farther developed by recent explorations.

In the N. ½ of Sect. 2, T. 39, R. 30, are boulders of iron-ore, and near the S. ¼ post of Sec. 34, T. 40, R. 30, magnetic attractions, which indicate the presence of the iron range. Near the S. ¼ post of Sec. 30, T. 40, R. 30, is a large exposure of ore; thence, following a line of magnetic attraction which leads about W. by N., we find in the centre of the S. E. ¼ of Sec. 25, T. 40, R. 31, another exposure of ore, and a continuation of the local magnetic variations, westerly towards the Menominee river, two miles distant. A range of iron ore, corresponding with this and probably its continuation, has been made out in Wisconsin, between the Brulé and Pine Rivers. Here are no less than nine large exposures of ore, the extreme ones 16 miles apart, which lie in one straight, narrow belt.

Immediately N. of this iron range is a broad belt of impure marble, equally regular, of greater thickness, but which apparently widens towards the W.

North of this, in the vicinity of the Sturgeon River, on Secs. 7 and 8, T. 39, R. 28, and Sec. 12, T. 39, R. 29, are local magnetic attractions and iron boulders, which are believed to mark the position of another geologically lower iron range, although no outcrop has been seen in this vicinity; but near the centre of N. ½ of Sec. 20, T. 40, R. 30, just N. of Lake Antoine, is an outcrop of silicious ore.

Strong magnetic attractions can be observed near the S. W. cor. of Sec. 22, and iron boulders in Sec. 27, and also on north shore N. of Lake Fumée, in T. 40, R. 30.

These indications make certain the presence of a second iron range, although it cannot be demonstrated that these several shows belong to one horizon.

These two ranges, separated by the marble, constitute the South iron belt. North of and underlying both, is an immense bed of quartzite, which is well exposed at the falls of the Sturgeon river, Sec. 8, T. 39, R. 28; also on Sec. 1, T. 39, R. 29, and Sec. 28, T. 40, R. 29, and at the southwest ¼ of Sec. 23, T. 40, R. 30, as will be seen by the map. This quartzite, although believed to be geologically conformable with the ore formations, is not parallel with them, running more northwesterly, and dividing in T. 40, R. 30, into two and perhaps three ranges.

North of this quartzite, and underlying the whole series already described, are the Laurentian, granites, gneisses and schists, which make up the *granite area*, already referred to as probably being barren in workable deposits of ore, and which, therefore, our investigations do not embrace.

South of the south iron range, already described, is a bed of chloritic schist, well exposed on the south shore of Lake Hanbury, Sec. 15, T. 39, R. 29, and on the Sturgeon river in Sec. 13. Immediately south is a second quartzite, which is quite different in its character from the bed already described.

Next south is a broad belt of argillaceous slate, running parallel with the iron range, and exposed at several points in T. 39, Ranges 28 and 29. (See map.) South of this, and embracing portions of the Menominee river, is a broad well-defined belt of chloritic, hornblendic and dioritic rocks, running parallel with the iron range, the harder members of which form the barrier rocks of all the falls in this part of the Menominee, and probably those of Pine river in Wisconsin. This series are perfectly exposed at Sturgeon Falls, Sec. 27, T. 39, R. 29, and at the great and little Bequensenec Falls, and Sand Portage, in T. 39, R. 30.

2. North Iron Belt.

The North iron belt or range has a course nearly due east and west, and is all embraced, so far as known, in the south tier of Secs. of T. 42, Ranges 28, 29, and 30. The most easterly dis-

covered exposure of ore, known as the Felch mountain, is in the N. ½ of Secs. 32 and 33, T. 42, R. 28, and is sixteen miles north and three miles west from the Breen mine, the position of which has been defined. Travelling due west, fragments of iron ore are found in N. E. ¼ of Sec. 31, T. 42, R. 28; after which no absolute proof of the presence of iron is found (although it is probably continuous) until we reach Sec. 31, T. 42, R. 29, where, in the centre of the section, is an immense exposure of iron ore in an E. W. ridge, which can be traced westerly halfway across Sec. 36 of the next Township. The natural exposure of ore on Sec. 31 is larger than at any other point in the Menominee region, and the quality is as good, if not better, so far as can be judged by surface indications. Magnetic attractions and iron boulders, found farther west and southwest on this range, prove its extension in that direction. Whether the westerly course continues, or whether it curves to the southwest, as seems probable from the position of the lower quartzite and local magnetic attractions in the northwest part of T. 41, R. 30, has not been determined. The latter hypothesis is most in accordance with the known facts, although the southeast dip of the quartzite on Secs. 17 and 18, observed by Dr. Credner, is not explained. If this hypothesis is true, the iron range should cross the Menominee somewhere in Secs. 24 or 25, T. 41, R. 31, into Wisconsin. There can be little doubt but that the North and South belts belong to one geological horizon, hence somewhere come together.

The existence of two distinct iron ranges in the North belt, does not admit of so easy proof as in case of the South belt. The facts which point towards this are the following: About one-fourth of a mile north of the iron range, already described as existing on Sec. 36, T. 42, R. 30, is a bed of marble running east and west, parallel with the iron, on both sides of which are slight magnetic attractions. Prof. Pumpelly found, "about 80 paces south of this marble, an outcrop of strata made up of layers of quartz, magnetic iron and chlorite," probably of no economic value.

Again, in the E. ½ of Sec. 35, are two parallel lines of feeble magnetic attractions, several hundred feet apart, and to the north are some large, angular boulders of magnetic ore; similar smaller boulders are found between Secs. 33 and 28, still farther west.

South of the iron deposits on Secs. 31 and 36, is a bed of marble, somewhat similar to the one already described as underlying the south iron range of the South belt, and possibly the equivalent of it, as the two have the same relative geological position. Farther south, immediately adjacent to, and overlying the granitic rocks, is a heavy bed of quartzite, which is undoubtedly the equivalent of the lower quartzite, already described as forming the base of the South belt. This quartzite at the S. ¼ post of Sec. 31, T. 42, R. 29, is characterized by the presence of mica scales in the bedding planes, and might be denominated a micaceous quartz schist. It has considerable resemblance to the rock, associated with the Cannon ore in the Marquette region. This fact possesses considerable geological interest in connection with the relative age of the Felch mountain ore deposit, which, I think, belongs in this lower quartzite. See Chap. III., Group H. mica schists, and below.

The Huronian rocks in the N. ½ of Sec. 31, are covered with horizontal layers of Silurian sandstone, hence cannot be seen. North of the iron on Sec. 36, is the marble already mentioned, which is peculiar in being filled in places with crystals of kyanite, giving the gray weathered surface of the rock a rough jagged character, like a coarse rasp.

Just N. of the N. ¼ post of Sec. 31, T. 42, R. 29, is an east and west range of gneiss rock, and still farther north a heavy bed of hornblendic schist. At numerous points east and west, through the centre of T. 42, Ranges 28, 29, and 30, are outcrops of similar hornblendic rocks, together with beds of mica schist and gneiss, traversed in places by dykes, and perhaps by beds of granite. This broad belt of hornblendic rocks is apparently represented in its westerly extension, where it crosses the Michigamme river, by the mica and chloritic schists and gneisses, so well exposed at the Falls of the Michigamme, Cedar Portage, Long Portage, Norway Portage and intermediate points in Towns. 41 and 42, R. 31. Similar rocks cross the Paint river, a few miles farther west. This series would correspond in their geological position, as they do partially in their lithological and topographical characteristics, to the hornblendic and chloritic series, already described as forming the southernmost formations of the South belt, and which there, as here, produce numerous waterfalls.

Near the centre of this hornblendic belt, in the north part of Secs. 21, 22, 23, and 24, T. 42, R. 29, is a line of comparatively feeble magnetic attractions, which seems to have no equivalent in the

South belt, unless it be in Sec. 28, T. 39, N. R. 18, E. Wisconsin; or in one of the beds of hornblendic rock at Little Bequensenec Falls, to be described hereafter, which contains many specks of sulphuret of iron and of magnetic ore.

This line of attractions, noticed in T. 42, R. 29, may represent the north edge of a basin, of which the North iron belt, already described, is the south edge; but I incline to the hypothesis, that it is an independent ferruginous range. No outcrop or boulder of iron has been seen upon it in Michigan, and it is doubtful if it is of any economic importance, although of much geological interest, as helping to elucidate the structure.

Returning to the most easterly exposure of iron on the North belt, the Felch mountain, we find a different and less complete sequence of rocks. Except some boulders about one mile west, no marble can here be seen. The Felch mountain ore rests immediately upon, and is bounded on the south by hornblendic, micaceous and gneissoid rocks, which are undoubtedly Laurentian, thus shutting out the marble and quartzite, already described as existing under the iron to the west. No indications, which would suggest the presence of a second iron range, can be found here. Within half a mile north the hornblendic schists are to be seen. At the N. ¼ post of Sec. 31, about 1½ miles westerly, is a large exposure of quartzite, running east and west, and apparently dipping to the north, although the bedding is indistinct. This may be the equivalent of the north marble range, Sec. 36, T. 42, R. 30, for quartzites sometimes pass into marbles in the Marquette region.

The Felch mountain ore, so called, is in reality a dull red jasper-like quartzite, containing numerous thin lamina and minute gash veins of very pure specular ore. It has somewhat the appearance of the "mixed" or second class ore of the Marquette region (see Chap. III. A), differing in containing less iron, and in the fact, that the ore lamina have less continuity. Considerable amount of a similar rock can be seen on the Penokie iron range, Wisconsin. I have a two pound specimen of specular ore from the Felch mountain, which is as rich as any I ever saw. The deposit is somewhat magnetic, the east and west belt of magnetic influence having considerable breadth.

It is not at all improbable, that better ores may be found adjoining this on the north, or possibly still further north, in a geological position corresponding with the ore on Sec. 31, T. 42, R. 29.

In the south half of Sec. 36, T. 42, R. 29, about two miles west of the Felch mountain, Prof. Pumpelly and Dr. Credner observed a variety of the lower quartzite, the character of which is important in connection with the age of the Felch mountain deposit. It has been described as containing mica enough on its planes of stratification, to make it semi-schistose, is porous, and contains thin streaks of magnetic iron in crystals, with here and there cubes of iron pyrites.

The above facts lead me to accept the hypothesis already advanced, that the Felch mountain ore deposit is itself in the Lower Quartzite. If we suppose the mica contained in the quartzite exposed at S. ¼ post of Sec. 31, and in the S. part of Sec. 36, to be replaced entirely by specular ore, a Felch mountain ore would be the result. This hypothesis is supported by the fact, that the Cannon ore, Sec. 28, T. 47, R. 30, is a quartz schist, having specular ore in its bedding planes, and which in a short distance changes into mica. (See Chap. III., Mica schist.) It should be noted, however, that while the Cannon ore is micaceous, the Felch mountain is eminently granular. The Cannon, like the Felch deposit, is at the base of the Huronian series, resting immediately on the Laurentian.

It has already been mentioned that *Silurian sandstone* capped the iron bearing rocks on N ½ of Sec. 31, T. 42, R. 29; the same is true in places on Sections 34, 35, and 36, in same Township, as also in Sections 31, 32, and 33, in the Township east. Passing to the South belt, we find the sandstone covering the iron series in Section 25, T. 40, R. 31, in Secs. 30, 29, 23, and 36, T. 40, R. 30; also in Sections 9 and 10, T. 39, R. 29, and in Sec. 15, T. 39, R. 28 immediately north of the Breen mine, as well as at numerous other points, which it is not necessary to mention.*

Explorations eastward on the two iron belts of the Menominee region, reveal the presence of this sandstone and its accompanying overlying limestone (calciferous sand rock), in greater quantity, even to the point of entirely covering up the Huronian and Laurentian rocks, which is done, so far as known, from near the east side of the Menominee iron region, all the way to the Canadian line at the Sault Ste. Marie. Local magnetic attractions, discovered by

* These irregular patches of sandstone are not represented on the maps.

United States surveyors at various points in this Silurian area, render it likely that the iron-bearing or Huronian rocks extend far to the eastward, connecting probably with the similar rocks of the north shore of Lake Huron, where they were first studied and named by the Canadian geologists. Pine explorers inform me, that they have observed dark-colored heavy rocks, which were somewhat magnetic, in the eastern portion of the Upper Peninsula. These may have been Huronian islands in the sea, in which the sandstones were laid down. This subject is discussed in Chap. II.

Like their equivalents in the Marquette region, the ore strata and accompanying rocks of the Menominee region usually conform in their strike with the general trend of the belts and ranges, and dip at high angles, thus presenting their upturned edges to the observer, and affording, where exposed, the best possible opportunity to observe the thickness of the beds and their mineral composition. But highly inclined strata, especially if they should be overturned, as is occasionally the case, are not favorable for making out the structure and sequence of the various beds. This question is farther complicated by the difficulty of distinguishing, in the case of the clay and chloritic slates, between the cleavage and bedding planes. The latter are sometimes very obscure, and have been confounded with the other, thus leading to erroneous results.

The geographical distribution of rocks in the Menominee region which has already been given in a general way, in connection with what has been said in Chapter II. concerning the structural relations of the Laurentian, Silurian and Huronian systems, leaves but little more to be said regarding the structure. The Laurentian area is the broad backbone of the great E. and W. anticlinal, on and against the north and south sides of which the iron series repose, dipping away from the axis; that is, the South belt south and the North belt north. This general structure, it will be observed, is similar to that presented by the Michigamme district on the south and the L'Anse-Huron bay districts on the north of the Marquette region, separated as they are by a great Laurentian anticlinal. It is probable that the Laurentian area of the Menominee region may wedge out at a point just west of the Menominee river, in the same way as do the Laurentian rocks of the Marquette region in the west part of T. 49, R. 33. (See Map I.)

In order to bring out the structure more fully for the information of the explorer and miner, three geological sections will be given, two on the South and one on the North belt. Like most geological sections, they are to a certain extent ideal, but are intended to correctly present the facts, together with such inferences as seem to be warranted. I should note that Dr. Credner's corresponding sections differ considerably in the hypothetical parts from mine, as will be seen by reference to his paper already mentioned.

Geological Sections, Menominee Iron Region.

Section A.

Projecting the more important rock exposures of the eastern portion of the South belt on one plane, which may be taken at right angles with the strike of the rocks, that is, N. 16° E, through Sturgeon Falls, Sec. 27, T. 39, R. 29, the following series will be found (See Map No. IV.):—

At the falls of the Sturgeon, Sections 8 and 9, T. 39, R. 28, is a group of strata, which divide rocks unmistakably Laurentian on the N., from the lower Huronian quartzite on the S., and which Prof. Pumpelly and Dr. Credner regard as of Laurentian age, but which seems to me to admit of some doubt, as they conform with the bedding of both systems (all being conformable) and have lithological affinities with both.

Prof. Pumpelly describes them as follows, beginning with the uppermost strata:—

1. Talcose slates, soft, light-greenish, gray, with distinct ripple-marks.

2. Four beds of conglomerates, consisting of more or less rounded fragments of quartz, granite and gneiss, 15 to 30 feet wide. See Spec. 65, State Coll., App. B, Vol. II. This conglomerate has not been observed elsewhere, although a somewhat similar rock outcrops on Sec. 10, T. 42, R. 28.

3. Underlying the series are two beds of protogine gneiss, of reddish color, separated by a bed of chloritic schist; the upper one of the beds of protogine encloses a segregated vein, two feet wide, of a mixture of magnetic iron and sulphuret of iron, which does not promise to make a workable deposit.

North of this series, at the head of rapids on Sec. 9, T. 39, R. 28, unmistakable Laurentian rocks occur, but which appear to be conformable with the Huronian. The chief varieties found here as well as elsewhere in the Menominee region are,—a granite (in places porphyritic) syenite, mica-gneiss, with some mica-schist, hornblendic-gneiss and schists, chloritic and talcose gneiss, with some chloritic and talcose slates.

I. The lowest, geologically, and most northerly formation which is unmistakably Huronian in the South iron belt, is a *quartzite*, which outcrops conspicuously at the Falls of the Sturgeon river, Sec. 8, T. 39, R. 28 (not Sturgeon Falls), where it is not far from 1,000 feet thick, and rises to an elevation of over 200 feet above the river. It is usually light-gray, massive, compact, and often semi-vitreous, with indistinct bedding; has more the appearance of vein quartz than the Marquette quartzites. In places it shows ripple-marks with great distinctness; the weather has no appreciable effect on it.

This formation outcrops conspicuously, forming high ledges on Sec. 9, T. 39, R. 28, on Sec. 1, T. 39, R. 29 and Sec. 28, T. 40, R. 29. A quartzite, believed to be the equivalent of this, outcrops near the N. W. cor. Sec. 26, T. 40, R. 30. The Felch mountain iron deposit is also supposed to belong to this formation, as has already been explained.

II. A quartzose *sandstone* and conglomerate rock, which has a lithological character more allied to the Silurian than the Huronian, seems to overly this quartzite on the S., outcropping near the S. W. cor. of Sec. 2, T. 39, R. 29, and on the E. bank of Sturgeon river, on Sec. 8, T. 39, R. 28. But little is known about it, and its existence as a member of the iron series is not absolutely proven. From its soft, friable character it would more likely be found under swamps than on elevations.

The marble outcropping in Sections 24 and 25, T. 40, R. 30, would appear to occupy the same horizon. The same marble may exist on this geological section, but it has not been seen; the formation we are describing may be its equivalent.

III. The existence here of a range of slightly *magnetic* ore is indicated by angular boulders of lean ore in the valley of the Pine river, Sec. 12, T. 39, R. 29, and by magnetic attractions, Secs. 7 and 8, T. 39, R. 28. It does not, however, outcrop in this vicinity.

The hypothesis assumed for the structure of the South belt would make this ore the equivalent of the range known to exist north of Lakes Antoine and Fumeê, in T. 40, R. 30. It is possible, as will be seen hereafter, that this conjectured iron range may be the equivalent of the main iron deposit of the North belt.

IV. Crystalline *limestone or marble*.—This formation has an immense development in the South belt, far greater than in the other, its thickness being probably greater than that of the quartzite I. It is generally thinly bedded, and usually of a light-gray color, but is sometimes reddish, yellowish, or bluish.* The upper portion contains thin bands of slate, in which it resembles the marbles of the Marquette region, but differs from them in being freer from silica, less variegated in color, having fewer joints, as well as in being immensely greater in its extent, and more dolomitic. The Marquette marbles are indeed but calcareous beds in the Lower Quartzite (V.) of that series, there being no proper marble formation in the rocks of that region.

A piece of marble from near the Breen mine gave Dr. Rominger carbonate of lime, 61 per cent.; carbonate of magnesia, 34 per cent.; hydrated oxide of iron and manganese, 1 per cent.; and silicious matter, 0.25; which composition would make the rock rather a dolomite than a limestone. Specimen No. 66, State Collection, App. B, Vol. II., came from Sec. 11, T. 39, R. 29. Five specimens from this locality gave an average specific gravity of 2.81, approximately determined. Dr. Rominger gave attention to the value of this rock for building. (See his Report, Part III.) Large outcrops of marble occur on the south side of the Pine river on Secs. 11 and 12, T. 39, R. 29, and on the Sturgeon river, Secs. 17 and 18, T. 39, R. 28.

V. The principal *iron ore formation* of the South belt overlies, on the south side, the formation just described. It is made up chiefly, so far as is now known, of silicious specular slate ores, corresponding nearly with the so-called flag ores of the Marquette region. There is generally such admixture of magnetite as to produce moderate variations in the needle, but no evidence of the existence of a large body of magnetic ore. Specimen 68, State Col-

* The weathered surface is often rough, from minute ridges, caused by the more silicious layers, which best resisted the weathering.

lection, App. B, Vol. II. is from Sec. 11, T. 39, R. 29. At the Breen mine some very good soft hematite occurs in the same formation, which promises to be in workable quantities. See Specimen 67, State Collection, App. B., Vol. II. This ore would probably be found elsewhere if sought for, but it never outcrops. A blackish, porous ore, hematitic in its character, containing 56 per cent. of iron and nearly 1 per cent. of manganese, was found in a pit at the ¼ post between Sections 9 and 10, T. 39, R. 29, but its extent was not determined. Boulders of the same ore were seen in other places on the range.

The best exposures of the hard ores of this formation in the vicinity of the Sturgeon river, besides the Breen mine, are in Secs. 11, 10, 9 and 6, T. 39, R. 29. These ores will be described more fully, and analyses given hereafter.

VI. On the south shore of Lake Hanbury, which lies in Secs. 9, 10, 15 and 16, T. 39, R. 29, is an extensive outcrop of *chloritic schist*, the most easily splitting planes of which strike west by north, and dip south at a high angle. A similar rock, believed to be the same bed, can be seen on the Sturgeon river, near centre of Sec. 13, T. 39, R. 29. South of Lake Hanbury, 200 steps, is a rock partaking of a dioritic character, but which is probably a harder granular form of the same schist. Such rocks often graduate into each other in the Marquette region (Chap. III.). This schist may probably underlie Lake Hanbury and the swamps easterly and westerly from it.* It is represented on the section as following in its foldings formations VII. and VIII., described below. It is at least possible that this formation may be the same as the Menominee river diorites and chloritic schists, IX. and X., there brought to the surface by another series of more southern folds. But this hypothesis is not assumed in this discussion.

VII. *Clay-Slate.*—At 350 steps south of Lake Hanbury, on lines between Secs. 15 and 16, T. 39, R. 29, is a bluish and greenish gray slate, showing indistinct contorted bedding, with prevailing dip to *north;* the cleavage planes of which strike about north 70° west, and dip 80° to south. Veins of white quartz occur in

* Since the above was written Professor Pumpelly has informed me that he observed a large outcrop of marble south of the iron formation III., in T. 40, R. 30, which will be described below under Section B. This marble may fill the apparent blank existing at Lake Hanbury.

these planes. At 550 steps south of the lake, a similar slate is found dipping *north* under the quartzite VIII., next to be described. It is believed that these two outcrops of slate, are the opposite sides of a synclinal trough, which holds the quartzite.

In the N. E. ¼ of Sec. 20, T. 39, R. 29, is an outcrop of talcose clay-slate. In Secs. 29 and 39, T. 39, R. 28, are several outcrops of dark colored, finely cleavable, but indistinctly bedded clay-slates. It is assumed that all these outcrops are parts of bed VII., which is folded into a synclinal and partial eroded anticlinal, as represented on section A of Map IV.

I am not in possession of sufficient facts to demonstrate the precise relations of these beds to each other, but the general fact is established by the northerly dips observed by me on Secs. 14, 15 and 16, that there are at least two folds between the iron range and the Menominee river, which probably reduces the estimated total thickness given in Dr. Credner's paper (18,000 feet), one-third. See page 175.

VIII. Associated with the clay-slates south of Lake Hanbury, is a bluish gray *quartzite*, which weathers into a brown, friable sandstone,* and in places reticulated with fine veins of quartz. At 550 steps south of Lake Hanbury, on line between Secs. 15 and 16, T. 39, R. 29, this quartzite is underlaid, as has been mentioned, by the clay-slate, VII., the division plane dipping plainly to the north at an angle of from 45° to 75°; the same rocks with the same northerly dip were observed farther east, on Secs. 15 and 14. This quartzite may be simply a local bed in the clay-slate formation, hence not entitled to a distinct number. The marked contortions both in the clay slate and quartzite are noticeable, and point unmistakably to the presence of a great fold. The cleavage planes maintain their east-west strike and southerly dip.

IX. This number is intended to include the soft *magnesian schists* (chloritic, talcose, and probably argillaceous) occurring so abundantly along the Menominee river, in the vicinity of the mouth of the Sturgeon, as well as at the several falls above. They will be more particularly described under geological section B.

* "Iron slate" is marked on the United States plats at this locality. The brown color of the quartzite has something the appearance of iron rust. The very feeble magnetic attractions existing along this range, indicate the presence of magnetite.

X. This formation is designed to embrace the granular *dioritic* rocks which form the barrier of the Sturgeon and other falls above, for 20 miles. It varies considerably in character, but on the whole bears a strong family resemblance to the granular diorites of the Marquette region. A peculiar gray variety, occurring at Sturgeon Falls, Sec. 27, T. 39, R. 29, is illustrated by Specimen No. 65, State Collection, App. B, Vol. II. This is the formation, it will be remembered, which in its supposed westerly prolongation into Wisconsin, produces the falls in the Pine river, and near them becomes iron-bearing. If the hornblendic schists mentioned as occurring in T. 42, are Huronian, they are probably the equivalents of this formation.

XI.—South of X., on or near the Menominee river, in south part of T. 39, R. 29, are several exposures of what appear to be *magnesian schists* and *protogine*, the structural relations of which to the rocks already described have not been made out. A rock similar to the protogine was observed in Sec. 13, T. 42, R. 30, and would there seem to have about the same relative position to the North belt that this has to the South belt.

Geological Section B runs northeast by north, across T. 40, R. 30, cutting Lake Antoine, and passes near the head of Great Bequensenec Falls. (See Map IV.)

I. Lower *quartzite*.—This formation appears far more conspicuously in this section than in A, owing to the double fold hypothetically introduced to cover the facts observed in the N. ½ of T. 40, R. 30. The large exposure of quartzite lying against the Laurentian, on Secs. 1 and 2, and the numerous angular boulders on Secs. 7 and 8, with the outcrop of quartzite near S. W. cor. of Sec. 23, taken in connection with the granite exposures on Secs. 4 and 9, lead one to the conclusion that one bed of quartzite, forming a synclinal basin under the Pine river and an eroded anticlinal to the south, best reconciles the facts observed. The lithological and topographical characteristics of this quartzite have already been given under A, and need not be repeated.

II. This formation was represented on A by friable sandstone and conglomerate, not observed near this section; the blue and pink *marble* outcropping near centre of Sec. 25, and the marble at the N. W. cor. of Sec. 24, are assumed to belong to one horizon

(as shown by map and section), which is supposed to immediately overlie the quartzite. There is no reason to believe that this formation has any great thickness.

III. The "shows" and "signs" of ore to which this number was attached on section A, have developed into certainty on this section, where, near the centre of the N. ½ of Sec. 20, T. 40, R. 30, a considerable outcrop of *iron ore* is seen in the bottom of a small ravine. It is a silicious, red oxide, resembling in its general character the great ore formation of section A. Its continuation eastward is made certain by the magnetic attractions on the south line of Sec. 22, by the iron boulders of N. E. ¼ of Sec. 27, and on the north side of Lake Fumeê, on Sec. 26. Except the slight attractions noted by United States surveyors, at N. E. cor. of Sec. 30, T. 40, R. 29, there is no connecting link, so far as known, between this deposit and the indications of this bed on A. It is not proven that they are identical. Dr. Credner, as will be seen by reference to his paper, believes the ores on the north side of the lakes are the equivalents of those on the south, the two being connected by a synclinal fold.

IV. Crystalline *limestone or marble*. There are immense outcrops of this rock in the S. part of Secs. 34 and 35; large exposures on the S. shore of Lake Antoine; boulders on the W. side of Sec. 30, all in T. 40, R. 30, and a continuation of the boulders in Sec. 25, in the Township west. The apparent thickness is greater than was shown on A., which may be owing to a crumpling or short abrupt folding of this part of the formation; or, it may be due to an actual thickening of the formation to the westward.

Two outcrops referred to, deserve especial mention: that in the N. W. fractional ¼ of Sec. 29, contains beds of a sandy and almost conglomeritic rock, which is associated with thin beds of dark-gray argillaceous limestone. The outcrop on Sec. 35 is the largest marble outcrop in the Menominee region, it being over 1,200 feet wide. As the dip is at a high angle to the S., the perpendicular thickness of the bed cannot be less than 1,000 feet. The S. part of the outcrop shows bands of limestone alternating with thin seams of quartz.

V. The *main iron formation* is marked by an outcrop in the centre of S. E. ¼ of Sec. 25, T. 40, R. 31, and by another which forms the west end of a high ridge on line between Secs. 30 and 31, T. 40, R. 30, the two being connected by a line of magnetic influence.

Attractions also exist near the south ¼ post of Sec. 34, T. 40, R. 30, and in the N. W. ¼ of Sec. 2, T. 39, R. 30, are iron boulders. There is at present (October, 1872) no reason to believe that the ore in Towns 39 and 40, R. 30, is less in quantity, or differs in quality from that already described under the corresponding formation of geological section A.

VI., VII. and VIII. The hypothetical place of these formations on section B, is covered by deep drift—constituting the sandy terraces of the Menominee river. No outcrops of any kind can be seen on this belt of rocks, either in Ranges 30 or 31, except a large exposure of marble observed by Prof. Pumpelly, just south of the ¼ post, between Secs. 32 and 33, which corresponds in strike and dip and in general lithological character with marble formation IV. Reference to the map will show that this rock has no observed equivalent on A, where, if it exists at all, it should be found under Lake Hanbury.

I must confess that the existence of this marble, but lately made known to me, points to the existence of folds in the neighborhood of Lake Antoine, not suggested by my geological sections.

IX., X. The chloritic, hornblendic, and dioritic rocks embraced under these two formations are well exposed at the Great and Little Bequensenec Falls, and at Sand Portage, all in T. 39, R. 30. These falls afford an unsurpassed opportunity to study this series, which was carefully done by Dr. Credner, who made out the following section at the upper fall from north to south :—

a. Crystalline hornblendic rock, consisting of light to dark-green hornblende in crystalline masses, white feldspar, a little chlorite and some quartz.

b. Talcose rock, consisting only of fibrous talc, which forms a kind of soapstone in three heavy beds.

c. Fissile talcose silicious slates, of a reddish color, with small crystals of orthoclase.

d. Soft talcose slates of light green color.

e. Chloritic slates, dark green, with spots and layers of clayish red oxide of iron.

f. Hornblendic rock, dark green, crystalline, coarse-grained to aphanitic, with specks of sulphuret of iron.

By the Little Bequensenec Falls the following series of strata is laid open, from north to south :—

a. Talcose chloritic slates, with a great many segregations of quartz.

b. Hornblendic rocks, with much dark-green chlorite, and many specks of sulphuret of iron and magnetic iron ore, 35 feet.

c. Soft fibrous soapstone in two heavy beds, with some sulphuret of iron, 8 feet.

d. Talcose slates, fissile, with many layers and segregations of white quartz and red limonite.

e. Chloritic slates, 10 feet.

f. Bed of hornblendic crystalline rock, 12 feet.

g. Chloritic slates with seams of iron pyrites, 30 feet.

h. Fibrous talcose slates, reddish, with bands of green color.

i. Chloritic slate.

Geological Section C. (North Belt). On line between Ranges 29 and 30, T. 42.

I. A *quartzite*, which is micaceous at S. ¼ post of Sec. 31, and in south part of Sec. 36, T. 42, R. 29, and ferruginous at the Felch mountain. The lithological character and stratigraphical position of this formation have been fully considered. Although it differs considerably in its character from the equivalent formation of the South belt, there can be little doubt but that it is the same.

North of this quartzite is a considerable breadth of low damp ground, with no outcrops.

II. Crystalline *limestone or marble*, of a quite pure snow-white, to reddish granular variety, outcrops immediately south of the iron on Sec. 31. In the southeast ¼ of Sec. 35, T. 42, R. 30, is an outcrop of marble presenting very distinct bedding planes, which dip to the north. These two outcrops define a range parallel with the quartzite, and probably belong to this bed, II. Another outcrop of marble near the centre of Sec. 35 cannot be reconciled as belonging to this formation, and there is some uncertainty as to whether it lies above or below the iron formation. If below, then it would have the same relative position to the iron as the outcrop first mentioned above. More facts are needed to establish the relations of these marbles. As will be seen by comparing sections C and B, it is assumed that the limestones marked II., on each, are equivalents of this bed.

III. The great *iron-ore formation*, which extends easterly and westerly across Sec. 31, half way across Sec. 36, and probably much

farther each way, has already been partially described. This bed is apparently the equivalent of III. of the South belt, but it is certainly more extensive, and, so far as can be seen, contains better ore. If this hypothesis be correct, then the upper and main iron formation of the South belt has no representative in the North belt, unless it be indicated by the slight magnetic attractions already mentioned as having been observed in the north part of Sec. 36. The strongest indication of the continuance of this formation eastward is to be found, so far as known, just six miles due east, in the N. E. ¼ of Sec. 31, T. 42, R. 28, where Prof. Pumpelly observed numerous large angular fragments of specular iron ore, associated with fragments of marble. This deposit should, on this hypothesis, pass just north of the Felch mountain, in its eastward prolongation.* The quartzite near the north ¼ post of Sec. 31, T. 42, R. 28, would, on this hypothesis, be the equivalent of the before mentioned marble in Sec. 36, seven miles west.

IV. Crystalline *limestone or marble*, containing crystals of kyanite, outcrops about 300 steps south of the north ¼ post of S. 36, T. 42, R. 30. Several outcrops of the same rock occur a short distance to the west, and a little south, indicating the probable existence of a large deposit of this rock. Except in the presence of the kyanite crystals, which gives to a weathered surface the rough character heretofore described, this rock has much the character of the marble, with corresponding number of geological sections A and B. Whether these marbles are equivalents is not proven, but it is assumed as being more in accordance with the facts than any other hypothesis.

V. An interesting fact in connection with the limestone outcrops on Sec. 36, just described, is the presence of a very noticeable magnetic attraction on both sides of the marble, or rather associated with it.

Prof. Pumpelly observed south of one of these outcrops of marble "strata made up of layers of quartz, magnetic iron and chlorite, containing garnets, and resembling some of the strata at Republic Mountain, Marquette region." These attractions

* The blank space north of and above the iron formation III., on section C, is marked by no outcrops except Potsdam sandstone, which covers the Huronian rocks on Sec. 31, as has been already stated.

are probably due to this rock, which is certainly but a poor representative of the great upper iron bed of the South belt.

VI., VII., VIII. No other rock was observed on this section for several hundred paces; this space may or may not be filled by these formations, which, so far, have only been seen on geological section A. The numbers are introduced here, in order to carry along the hypothesis of structure which will best reconcile and present the observed facts.

IX., X. Just north of the north ¼ post of Sec. 31, T. 42, R. 29, is a large outcrop of gneiss, with thin layers of granite, and adjoining this on the north is the most southerly observed outcrop of the great hornblendic and mica schist series, the geographical extent and general structure of which have been fully considered. Whether this series of schists are the equivalents of beds IX. and X., which occupy the immediate valley of the Menominee, cannot be established. They have the same relative position to the iron ore, marble and quartzite series, and similarity in their lithological character. It must be admitted, however, that the lithological affinities of this series of rocks of the north belt are decidedly Laurentian rather than Huronian. The gneiss and granite outcrop, above described, may be almost regarded as a typical Laurentian rock in its appearance. If future investigations prove them to be Laurentian, a very troublesome structural problem would be presented here, as we would have Laurentian rocks conformably *overlying* beds, unmistakably Huronian. There seem to be fewer difficulties in supposing that the Huronian rocks of the Menominee region embrace lithological families not, so far, found represented in the equivalent series in Marquette region.

An important observation may be made here bearing on the variable thickness of the Huronian series, or else pointing unmistakably to tremendous folds in the rocks of the South iron belt,—it is this: the superficial breadth occupied by formations I. to VIII. inclusive, is nearly four times as great in the South belt as in the North. A portion of this difference may be accounted for by the thinning out of this series to the north; but the folds figured in geological section A, and possibly others not determined, would, I think, account for the greater part of this discrepancy.* There are no evidences of any folds in the corresponding series in the North belt.

* See page 169.

A range of marble associated with quartzite, chloritic and talcose rock, and overlaid by a chloritic gneiss, with beds of chloritic schist and gneissoid conglomerate, the whole dipping at a high angle to the south, passes about five miles north of the North belt. These may represent the north side of the trough or basin, of which this iron belt is the south outcrop. No iron has, however, been found, as far as I know, on this range.

Along the Menominee river, where it crosses this broad schistose belt which lies north of the North belt, is a series of north and south dips, observable at the Cedar, Long, and Norway portages, which point unmistakably to intermediate folds in these rocks, whose thickness, therefore, may not be very great.

Nothing remains to be said regarding the Menominee iron region which is of practical importance to the explorer, miner, or capitalist, and which would properly come within the scope of this work, except a statement as to the *quality of the ore*. The quantity has already been described as great, and the chances to mine all that could be desired. The distances by rail from shipping port and grades are most favorable. If the ores are of first quality, this region has a future which will only be surpassed, if it is surpassed, by the Marquette region, now developed to that extent that its ores produce nearly one-fourth of all the iron made in the United States.

Unfortunately at this time the question of quality cannot be fully answered, for the simple reason that up to the date of my last visit, in October, 1872, comparatively little exploring had been done, and iron deposits very seldom expose naturally their best ores; these have to be found by digging. This subject is fully treated in Chap. VII.; but I will repeat here that ninety-nine hundredths, if not nine hundred and ninety-nine thousandths, of all the ore outcropping in the Marquette region (and there is an immense amount of it) is not merchantable, according to the present standard for shipments. Soft hematite ores never outcrop; therefore if pure high grade ores be abundant in the Menominee region, they might not yet have been found from the little work that has been done.

The facts observed by me are as follows, taking the several iron locations in succession:—1st, The *Breen mine* on N. ½ of N. W. ¼ of Sec. 22, T. 39, R. 28, **South belt**. Three kinds of ore occur at this locality, the predominating variety (constituting perhaps

four-fifths of all exposed) being a lean, silicious, slaty or flaggy ore, resembling the Iron mountain and Teal lake ores of the Marquette region. It varies in quality from a ferruginous quartz schist, containing but a few per cent. of iron, up to masses as good, if not better, than the second-class or flag ores of the Marquette region, with occasional richer streaks. Careful mining and selecting would produce an ore of this kind that should yield say 45 per cent. in the furnace, but it would be apt to "work hard," from the large amount of silica, and produce a hard iron, suitable, perhaps, for rail-heads. (See Iron Ores, Chap. III.) What percentage of the whole mass would be of this degree of richness, practical mining only can determine; from what could be seen in October, 1872, I should say not exceeding one-third.

The next variety in abundance is a soft, earthy, dark-colored hematite, resembling in its general appearance the Negaunee hematite ore of the Marquette region. A sort of irregular pocket of this ore was found lying in the first described variety, appearing as if it may have been produced by a partial decomposition and disintegration of the flag ore,—that is a secondary form of it. This hematite pocket, so far developed by the shafts and trenches, is of sufficient size to work advantageously, but is divided through the centre by a bar of very silicious ore. Several "shows" of this ore were found in other places, but none were proven to be of workable extent. See Spec. 67, State Coll., App. B, Vol. II.

The third variety of ore is best in quality, but, so far as known, least in quantity. It can be seen near the mouth of a drift on the south side of the ridge next the swamp, where a bed two or three feet thick was passed through, flag ore being found to the north of it. This is a hard, more or less porous, bluish, heavy, red ore, of a hematitic character, and has considerable resemblance to the so-called Jackson "hard hematite." It would undoubtedly work well in the furnace, and would yield not less than 60 per cent. of metallic iron. There are reasons to suppose that there may be a workable bed of this ore on the property; but judging from what is to be seen at the drift above mentioned, it may be under wet ground.

On the whole, it may be said of the Breen location, that the great amount of ferruginous schist there developed, and the tendency shown by it to pass into soft hematite, render it very probable that a considerable quantity of workable ore of this kind

may exist. The absence of local magnetic attractions, and of boulders of rich hard ore, leads me to consider it doubtful whether any rich specular and magnetic ores, such as are now produced in the Marquette region, will be found here.

The ore range probably extends east and west, the entire length of the "80," or one-half mile, forming a ridge where the explorations have been made, from 20 to 30 feet high, bounded by a swamp on the south side. The whole iron series dip south, and are underlaid on the north by soft shaly magnesian and argillaceous rocks.

Sections 6, 9, 10 and 11, T. 39, R. 29. The ores on these sections form what appears to be a continuous deposit, and are so much alike in their general character that they can be more commonly and briefly described together. Except a few trenches dug by the Canal Co. on Secs. 9 and 11, and some test-pits sunk this season on Sec. 6, no work had been done on this range at the time of my last visit. Here, as at the Breen, the prevailing variety, in fact the only variety which I saw in quantity, was the silicious flaggy ore already described. The quantity of this ore is enormous, forming as it does the south face, and, perhaps, the great mass of a considerable ridge running west by north. The opportunity for attack by open cuts into the south face of this ridge is unsurpassed. Like the hard ores at the Breen, they vary greatly in richness,—from a quartz schist slightly impregnated with iron up to specimens, and even considerable masses which will yield 50 per cent., and occasionally a specimen that contains 60 per cent. of metallic iron. The prevailing variety, however, is represented by Specimen No. 68, App. B, Vol. II., from Sec. II., which contains from 25 to 45 per cent. of iron.

Dr. Credner reports having found, in "Cut D, on Sec. 11, 28½ feet of good fine-grained, steel-gray iron ore, with here and there a narrow streak of silicious ore, but in such a small proportion as not to spoil the good quality of the mass. The whole series gives a dark-red streak." Specimens designed to represent the average of this deposit gave Dr. C. F. Chandler 52 per cent. of iron. In another place he found a bed "6 feet thick, supposed to be very rich ore." I did not find these trenches (as afterwards appeared), although I designed to see all, and had with me two men, who helped to dig them. Dr. Credner further reports an aggregate of 139 feet

in thickness of "workable ore" on Sec. 11, but my own observations lead me to question this, unless the standard of furnace-yield be put considerably lower than at present. It is unwise, however, to predict at this time what thorough explorations may reveal.

The ore on Sec. 9 is very similar to that on 11, but on the whole (so far as can be seen) not so good: the same may be said of that on Sec. 6. Two smaller boulders of rich specular slate ore were found on the latter section, but no large ones. Occasional narrow seams of tolerably rich ore were found, one of them over one foot thick, but nothing that looked like a workable deposit. At the ¼ post between Secs. 9 and 10, north of Lake Hanbury, are to be seen several boulders of a black, porous earthy ore resembling somewhat varieties of the Negaunee manganiferous hematites; the same ore was found in place in a pit near by, and a large boulder of it near the center of S. ½ of N. W. ¼ of Sec. 6, and at other points. A hand specimen gave Mr. Jenney 56.44 per cent. of metallic iron, less than 16 per cent. of insoluble silicious matter, and nearly 1 per cent. of manganese. It is unlike the Breen mine hematite, and, in fact, unlike any Lake Superior ore I have seen. It is not improbable that workable deposits of it may exist, which being soft would not be likely to produce outcrops or boulders. I think it is well worth investigation. I have some reasons for supposing that this ore may be Silurian.

The next exposure of ore west of Sec. 6 on the south range is near the ¼ post between Sections 30 and 31, T. 40, R. 30. This ore is softer and more slaty than those already described, although belonging to the flag ore family. It is apparently more argillaceous, and outcrops conspicuously in several places west of the ¼ post, dipping at a high angle to the *north*, which would necessitate an *overturned dip* in order to harmonize with the hypothetical geological sections given on the map. The exposed bedding-planes are bright and specular, giving the ore the appearance of being richer than it really is. The ore exposed here may yield 45 per cent. in the furnace; see analysis No. 254, Chap. X.

From this locality we are led by a broad belt of very moderate magnetic attractions west by north for half a mile, to the iron ore exposed in the centre of S. E. ¼ of Sec. 25, T. 40, R. 31, where the Canal Company have done some trenching; the exposure

here is not great, the ore being in a small ravine on high ground. It is intermediate in character between the flag ores noticed, but most like the last. I followed the attractions about one-eighth of a mile west, to a point where the hill seemed to be capped with Silurian sandstone.

I have now mentioned in order, beginning at the east, all the main exposures of ore in the south range of the South belt, which has already been referred to as the most regular and one of the most extensive deposits of ore in the Lake Superior region; whether it is absolutely continuous for the 16 miles intervening between the extreme exposures, can only be determined by expensive explorations or actual mining.

Passing from the south to the north range of the South belt, we have but one exposure to consider, that near the centre of N. ½ of Sec. 20, T. 40, R. 30. This is in a small ravine, down which, to the south and toward Lake Antoine, a rivulet has its course in wet weather; the water has uncovered a narrow surface of flag ore similar to that seen on the south side of Sec. 30, but less slaty. Iron boulders are strewn along the ravine for over 100 feet. This ore is a red oxide, but holds enough magnetite to give it a moderate magnetic power.

Ten miles northerly across the granite region, from the last mentioned locality on Sec. 20, bring us to the main deposit of ore in the **North belt**—that on Secs. 31 and 36, of T. 42, and Ranges 29 and 30. The great extent of this deposit, and its favorable situation for mining, have already been commented on; it only remains to notice the quality of the ore. It is more granular and massive than the flag ore of the south range, and, as a whole, contains less silica and more metallic iron. The natural exposures of ore in the ledge are greater, no digging or uncovering at all being required to reach a great quantity of the ore. The best ore to be seen outcropping, is just southeast of the centre of Sec. 31: the top of the cliff is here about 100 feet above the low ground at its base on south side; and for about one-third of this height is a ledge of ore, from the foot of which the surface slopes rapidly to the low ground, affording the best possible opportunity for mining. This outcrop was carefully examined for a distance of several hundred feet in length, and from

the richest places to be found in it, 29 specimens of ore, of about one pound each, were collected, no two being broken from the same place. The specific gravity of these specimens was approximately determined on the ground, and was found to vary from 3.26 to 4.15, the mean of the 29 specimens being 3.71; this multiplied by 12, according to the empirical rule given under Explorations (Chap. VII.), gives 45 as the average percentage of the whole. An ore which actually analyzes 45 per cent. of metallic iron should yield say 47½ per cent. in the furnace, which is about what I consider this ledge of ore would work, if mined and sorted with ordinary care. Several ounces, chipped from five of the best hand specimens I could find, gave Dr. Wuth, of Pittsburg, 54.81 per cent. of metallic iron (See Analysis No. 98, Chap. X.). Separate analyses of ten hand specimens, selected from same locality by Prof. Pumpelly and Dr. Credner, gave Dr. Chandler from 49 to 64 per cent. of metallic iron, the average being 53.74 per cent. If this higher grade can be found in workable quantities (which is probable), then we should have a 55 per cent. ore, which, considering its granular and semi-porous nature, and the fact of its being a red oxide, would indicate an ore not difficult to reduce, and one which would sell in the present market.

No boulders were observed in this vicinity which would indicate a richer ore than the above of the red oxide variety, and no magnetic attractions were observed which would suggest a workable deposit of magnetic ore, although all the ores of this region are slightly magnetic. As hematite ores do not outcrop, and as no explorations have been directed to finding such ores, nothing can be said regarding them. My impressions are that they will be found on Secs. 31, 32, or 36 of the North belt.

The Felch mountain ore was fully described when considering the lower quartzite. It is totally unlike either of the preceding varieties, and more closely resembles the "mixed ore" which accompanies the rich specular ores of the Marquette region. The laminæ of ore are very rich, analyzing from 63 to 67 per cent. of metallic iron; but the large admixture of quartzite (at least three quarters of the whole) would render it unmerchantable at present. It is by its constitution particularly well adapted to *stamping* and *washing*, and on account of its proximity to several rapids and falls in the Sturgeon river, is well situated to be worked in this way,

when the market drives miners to this means of production, as it will sooner or later.

3. Paint River District.

Too little is known about the remote Paint river district, in Towns 42 and 43, Ranges 32 and 33, to enable me to give anything of interest regarding its geological structure. The Huronian rocks are extensively developed there, and contain deposits of hard hematite ore. I had the opportunity to examine only two localities, at the Paint River Falls, Sec. 20, T. 43, R. 32, and on Sec. 13, T. 42, R. 33. The ores are identical, and unlike any in the more easterly part of the Menominee region, in being richer in iron, freer from silica, and in containing more water. (See Analysis 68, Chap. X.)

Explorations now in progress will determine many of the unsettled questions regarding the ores of the Menominee region, especially of the South belt. I regret that I cannot embody their results in this Report, and thus give it a completeness that in the present state of my information is impossible.

CHAPTER VI.

LAKE GOGEBIC AND MONTREAL RIVER IRON RANGE.

An examination of this but little known iron-field was not contemplated in the original plan of the survey. But, having had occasion in the line of my profession to make some explorations there, a few of the general results obtained will be given, with a view of aiding future explorations, and of calling attention to a comparatively unexplored region. The probability of there being early railroad communication through this country, connecting the existing system of roads of the Upper Peninsula with the North Pacific, Minnesota and Wisconsin systems, now radiating from the west end of Lake Superior, attaches additional interest to this most western portion of the Upper Peninsula.

The facts observed and conclusions formed are the joint work of Prof. Raphael Pumpelly and myself, and have, so far as they bear on the stratigraphical relations of the four great systems of rocks, been in substance given to the public, in the American Journal of Science and Arts, Vol. III., June, 1872. Many rock specimens, gathered by us are minutely described by Mr. Julien, in App. A, Vol. II.

The iron range under consideration may be regarded as the eastern prolongation of the Penokie range of Wisconsin, as well as the western extension of the Marquette series, the whole being Huronian. The position of the range is tolerably well defined by magnetic observations and notes on the U. S. land office plats; on these we find mention of iron and magnetic attractions on Secs. 7 and 8, T. 47, N., R. 45, W., as also in Secs. 13 and 14 of the Town west. The belt of Huronian rocks, as made out by us, extends nearly east and west, through the north part of T. 47, Ranges 44, 45, 46 and 47, crossing the Montreal River in Secs. 16 and 21, of the last-named Township. Going east, the range was lost before it reached Lake Gogebic.

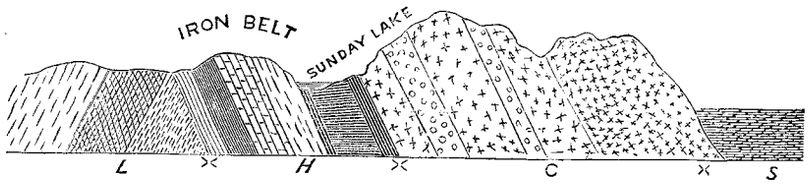
The geological boundaries of this range are fortunately of the most unmistakable nature, and render a detailed description of its position unnecessary. (See Map I.)

On the north is the high, broad, irregular ridge, or series of ridges, constituting the South Copper Range, the rocks of which are greenish and brownish, massive and amygdaloidal copper-bearing traps, their bedding being exceedingly obscure, with occasional beds of sandstone and an imperfect conglomerate. The strike of these rocks, so far as it could be made out, was east and west, with a dip to the north at a high angle, thus *conforming* with the Huronian rocks underneath.

Against and over the copper series on the north, abut the horizontally bedded lower Silurian sandstones, which are beautifully exposed on the west branch of the Ontonagon river, in Sec. 23, T. 46, R. 41. These sandstones form the surface rock, and occupy the broad belt between the two copper ranges from the region we are describing to Keweenaw bay, but taper to a point before reaching the Montreal river, in going west.

On the south of the iron-bearing rocks are a series of granites, chloritic gneisses and obscure schists, which, except the latter, are unmistakably Laurentian in their lithological character, and are *non-conformably* overlaid by the Huronian rocks. The general structural relations of the four great systems here enumerated are shown in the accompanying diagram. As the *non-conformability*

Fig. 12. Sketch showing Geological Section—looking west, between Lake Gogebic and Montreal River (in part ideal).



L. Laurentian rocks—gneiss, granite and schists, which are *non-conformably* overlaid by, H. Huronian—Clay slate, ferruginous and jasper schists, flag ores, quartzites and diorites, say 4,000 feet thick, which are *conformably* overlaid by, C. Copper-bearing rocks, chiefly greenish and brownish, massive and amygdaloidal traps, with occasional sandstones and conglomerate layers, which are *non-conformably* overlaid by, S. Lower Silurian sandstone, coarse quartz sandrock.

of the copper-bearing rocks and sandstones is doubted by some geologists, it should perhaps be stated that the actual contact was not seen. But the sandstones were observed lying horizontal, and affording not the slightest evidence of disturbance, within a few miles of highly-tilted copper rocks, which gave every evidence of having been elevated before the deposition of the sandstones. So far as my observation has extended, this rule is general; that is, no Lake Superior sandstone, which is unmistakably lower Silurian, has ever been found in any position other than nearly horizontal; and no rock which was unmistakably of the Copper series has been seen which was not considerably tilted. The fact that certain sandstones belonging to the copper series are very similar, if not lithologically identical with some of the lower Silurian sandstones, has helped to complicate this question. An interesting locality for study in this connection is the west fork of the Ontonagon river, just south of the Forest Copper Mine. I am not sure but that it affords an exception to the rule above stated, as at that point sandstones, *apparently* Silurian, dip south at an angle of 45°.

The best locality in which to study the character of the iron series in the West region, is on Black river and its tributaries, especially on the outlet of Sunday lake, T. 47, Ranges 45 and 46. Here will be found banded ferruginous jaspery schists, chloritic greenstones, brown ferruginous slates, black and gray banded silicious slates, silicious flag ores, several varieties of quartzites and clay slate. The whole series strike east and west, and dip north away from the granites and gneisses and under the copper rocks, at an angle of from 40 to 90°. Several varieties of the Huronian and Laurentian rocks of this vicinity have been examined by Mr. Julien, for descriptions of which see Appendix A, Vol. II. It will be observed from these descriptions that these rocks, although somewhat different from the Huronian series of the Marquette region, are still essentially the same; and I know of no good reason why merchantable ores may not be found amongst them. No ore, however, was found either in place, or in the form of boulders, which would pass for shipping ore in the Marquette region at this time. The absence of strong magnetic attractions renders it improbable that pure magnetic ores will be found here. The most encouraging indications observed pointed towards the existence of soft hematites, which may very likely be found of a quality and in quan-

tity to pay for working. The best "show" observed was in the south ½ of the S. W. ¼, Sec. 18, T. 47, R. 46. It is on the north-easterly side of an east and west ridge, where there is a large exposure of highly ferruginous quartzite in places holding hand-specimens of hematite ore of fair quality. As this kind of ore never outcrops, on account of its soft, earthy character, and as we had no facilities for digging, nothing more definite was determined.

CHAPTER VII.

EXPLORATIONS (*Prospecting for Ore*).

1. How Failures have occurred, and how to avoid Them.

The history of the development of a good many of our iron mining enterprises has been somewhat as follows:—The deposit is found, sometimes by accident, but often by systematic explorations made at the expense of corporations, firms, or individuals, by a class of men known as *explorers;* who are acquainted with woodcraft, are often miners, and who always have some knowledge of structural geology, the different varieties of ore, and the use of the miner's compass. A boulder of ore, red soil in the roots of a fallen tree, the variation of the magnetic needle, the proximity of rocks supposed to belong to the iron range, and often the outcrop of the ore itself, determines where digging shall be commenced.

If the indications are promising, before many marks are made the land is secured, if not already owned or controlled by those interested in the explorations. If government land, it is "entered" at the land office at $1.25 per acre, or $2.50 if within the limits of some railroad grant. If the land is "second-hand," already entered, it may be bought outright, or if the price be regarded as too high, a refusal is often taken with the privilege of exploring.

If the discovery is on the land of some railroad or mining company, it usually cannot be bought. In this case, all trace of the work done is often concealed, secrecy enjoined on all concerned, and the explorer lives in the vain hope that he may sometime have the opportunity to buy the land, an expectation in which he usually dies, as large corporations do not often sell iron deposits for small prices, if at all. Instead of this unwise course, explorers often sell their information to the companies owning the land, which they can usually do at a fair price. Our supposed exploring party having secured the land, begin to dig test-pits and trenches openly

and systematically. The solid ledge is usually soon found, which may prove to be some variety of iron ore, perhaps pure, but far more likely a "mixed ore" or lean flag ore, hence not merchantable.

Specimens (which I am sorry to say are apt to be the best that can be found) are sent in as *averages* of the deposit. Experts pronounce them shipping ore, and common talk asserts that So and So have a "good show" for a mine.

Soon the test-pits, trenches and drifts develop a workable width and length of what seems to the explorers to be merchantable ore. "Mixed with a little rock perhaps in places," but this occurs in most mines at the start. Experienced mining men visit the new deposit, examine it carefully, and assert honestly that "it looks better than did the Champion or Barnum locations when they first saw them."

The explorers select what they believe to be strictly *average* specimens of the ore (an impossible thing as will appear), which are sent to some distinguished chemist who reports, perhaps 65 per cent. of metallic iron, and only traces of sulphur and phosphorus, and expresses the opinion that the ore will *work well* in a blast furnace, and is identical with other well-known Lake Superior ores. This report, with the certificates of good practical mining men, and the opinion of some geologist who may have examined the locality, satisfies the owners that they have a workable deposit of "shipping ore."

Next in order, if it has not proceeded simultaneously with the above, is the organization of a company under the general mining law of Michigan,* which prescribes not to exceed 20,000 shares at $25 per share, par value. The property above mentioned is put into the new company at a moderate price; some prominent man of character and means is found to take the presidency of the company, his friends, with others, being "let in" on the "ground floor," and the None-such Iron Co. is organized and at work.

Building up a location is the next thing in order. To this end a contract is usually let to some French Canadian to build a dozen log houses for miners' families, a company's store, barn and shop. For this purpose the contractor lays out *fifteen different lines* on which to put the buildings, being governed in each instance by the ease with which the logs can be got together. In clearing for the foundations it is usual for the Frenchman to find a new deposit of ore

* App. I., Vol. II., contains an abstract of the Mining Laws of Michigan.

better than the one first found, to which a part of the mining force is at once transferred, the location of the buildings being changed so as to avoid the fragments which blasting has already begun to throw. The condition of affairs at the new location is at this period about as follows:—houses are going up rapidly, stripping is being pushed to the utmost, several "pairs" of Cornish men are sinking shafts or blasting off the "cap rock" so as to get at the ore. The contract for a first-class wagon road to connect with the State road has been let at $2 per rod, and a party of engineers are at work locating a branch railroad to the mine, and it is confidently predicted that a considerable amount of ore will be shipped from the mine that season.

About this time the president of the company—an old iron man, who has made a fortune by smelting 40 per cent. ores with anthracite coal in Eastern Pennsylvania—and a part of the board of directors visit the mine. One of the directors is an eminent lawyer who helped to "place" the property, another is a stockbroker who had made a fortune in Wall Street, a third is a railroad king, and another a successful whisky distiller. None but the president knew anything of iron before they came into the company. He is of course amazed at the richness of the ore, and tells the captain in charge of the mine truthfully, that he is throwing away as good ore as he ever used in his Pennsylvania furnaces. All collect and examine numerous specimens, which are submitted to the president and captain for their judgment as to richness. Nothing less than 50 per cent. is found, and the average is much higher. The lawyer who has fine muscular sense and a consciousness of its possession, soon discovers that he can judge accurately of the percentage of iron by handling the pieces of ore, and speedily becomes an authority with the broker and distiller. Specimens are hefted which contain 59, 61, 62½, 68, and finally one fine-grained fragment of steely ore, which, after careful manipulation in each hand, it is decided contains 75 per cent. of metallic iron. The captain unhesitatingly admits that to be richer than anything in the Jackson mine. Rock is found in several pits, but the captain explains that it is only greenstone which "caps" the ore, and proves by the magnetic needle which is "dead 90," that the ore is there. Being in a hurry he may not have faced the instrument exactly east and west.

Having spent one half-day in the examination of their property,

and becoming satisfied that it is first-class and will prove a profitable investment for themselves and friends, the company leave, having first instructed their superintendent to bend all his energies to getting out ore, without reference to quality, cost, or future condition of the mine—though the whole is not, of course, directly expressed. On their way East, the president perhaps sells a thousand tons or more to some furnace man who is a stockholder in the new company, and telegraphs back to the superintendent to ship it at once.

The foregoing sketch contains the elements on which many Lake Superior iron mining enterprises have been organized, and at the start operated. It is needless to remark that many such undertakings result in utter failure. In the copper region the proportion of failures is far greater, and in oil, gold, and silver enterprises overwhelmingly so. The average human imagination becomes temporarily diseased when stimulated by the chances of possessing hidden mineral wealth. Iron, being the least valuable of the metals, has less of this influence than the others, but is not entirely free from it.

It may interest those who are disposed to identify themselves with Lake Superior iron mining enterprises (and I believe no equal investment has paid better in past time or promises better for the long future) to know the cause of failure in such enterprises. Classifying them carefully, I find that about two thirds of the disastrous enterprises were based on deposits of ore the *quality* of which was not merchantable: they were not rich enough in metallic iron. The extraordinary richness of Lake Superior ore is not generally known. I have reports from 40 furnace stacks in which these ores are smelted, which show that the average furnace yield of 250,000 tons of magnetic and specular ore for 1870 was 65 per cent.

The amount of high grade hard ore is so great that consumers can usually get all they require, and will not buy an inferior grade. For this reason experienced iron men from other regions have often been deceived; they had not a sufficient realization of this question of quality. Marquette ores—which were rich compared with what they were used to—could not be sold on account of their leanness. The soft hematite ores are not considered in this connection.

The remaining third of the failures have come from a lack of *quantity*, the quality of the ore being satisfactory. It follows, therefore, that the question of first importance in a new iron mining

enterprise is to know—First, the *average percentage* of metallic iron in the deposit. What will the ore, *mined in the usual way, yield on the average when smelted in the blast furnace?* Second, approximately or relatively, *how much is there of it?* The failure to answer these questions correctly at the start has caused the loss of over one million dollars in the Marquette region during the last ten years, and the business is still going on. Experience is an expensive school, but is always full; no sooner does one class graduate than a new crop of "freshmen" take their places.

I believe it is not impossible nor even difficult to ascertain, at a moderate cost, the average amount of metallic iron, in any given deposit, sufficiently near for all practical purposes, and whether there is enough ore to pay for working.

It is the business of the explorer to find ore deposits and to determine approximately their extent and richness, thereby avoiding such failures as have been described above. This subject will now be considered under the several following heads:—

2. Prospecting and Woodcraft.

As considerable part of the iron exploration work now being carried on in the Lake Superior region involves camping out and a knowledge of woodcraft, some facts regarding this part of the business will not be amiss here, and are the more necessary because very little reliable information on this subject can be found in any book with which I am acquainted. There are no roads through large districts of country, which, in consequence, can only be reached by boats or walking; in either case a considerable part of the labor is *packing*, which means transporting everything on the backs of men. This mode of transportation costs about $9 per ton per mile at the present time, which is twenty-seven times as much as it costs to move freight on wagon-roads; it is, therefore, important to carry only such articles as are needed. Many an exploration enterprise has practically failed because the chief energies of the party were expended in carrying supplies and material which were not needed, while necessary things were left behind. It is safe to say that two times out of three, even in the case of experienced explorers, supplies do not come out equal. The party will be out of pork and have an abundance of flour, or the converse; will travel in a leaky

canoe for the want of a little pitch, or be barefooted because they had no awl; or ragged for want of thread; or suffering for food, where there is plenty of fish and game, because the salt had failed; or have their supplies wet for want of a piece of oilcloth. I have been in all these straits.

Organization of the Party.—Take the ordinary case of searching for mineral or timber, when an explorer and two men constitute the party. As packing is the heavy work, it is indispensable that all hands understand it. An average packer will carry 70 to 80 pounds and his blankets, but loads of 50 to 65 pounds are more common; across portages men often carry 100 pounds, and sometimes a barrel of flour weighing 200 pounds; but the packer who carries 70 pounds and his blankets, 10 to 15 miles per day, on a trail, or 5 to 10 miles through ordinary woods, has earned the $2.25 clear per day, which is the present average wages.

Next to packing, cooking is an indispensable qualification. No man is fit to go in the woods who cannot cook; and many a woodsman, with a frying-pan and two tin pails, will, over his campfire prepare a better cooked meal, and in less time, than can be produced in one-third of the kitchens of the country, with all the appliances that belong to modern housekeeping.

An ability to handle a canoe in rapid water is almost as indispensable as the others. Three men with a month's supplies will require a 16-foot canoe, which will weigh, when dry, about 125 pounds, and can easily be carried across a portage by one man; such a canoe will cost, in the Menominee waters, at this time, $15 to $30. The Bad water Indian village is the chief source of supply.

Next to packing, cooking, and canoeing, an ability to travel through the woods, and locate himself, by the United States Land Office plats, or maps made from them, aided by a pocket-compass, is essential. A man who possesses these qualifications is a woodsman, and has a calling which, if he is honest and intelligent, will be profitable in the Lake Superior region for a long time to come. If, in addition to these requirements, he is a judge of timber, and can keep simple accounts, write letters, and locate himself by the "40," then he is fit to lead a party, and become a "pine-looker," or "cruiser." If he add to this, a knowledge of the more common rocks and minerals, and an ability to make rough maps or

plans of ground, then he is an explorer. Such men can command from $4 to $6 per day clear, with full time, and often an interest in what they find besides; or if they choose to examine lands (either timber or mineral) on their own account, they can usually sell their "notes" at so much per acre, subject to re-examination; or some one may purchase the land, paying the explorer for his services in an undivided interest in them. Notes of pine lands now sell readily at from 50 to 75 cents per acre.

Supplies.—Pork, flour and tea embrace all that is absolutely essential in the way of supplies, though sugar, beans and dried fruit are usually added; rice, oatmeal or wheat grits are also generally carried, and a little hard bread is convenient, to which a few pounds of cheese may be supplemented. Pickled ham, especially in summer, may take the place of part of the pork, and smoked beef is sometimes used.

The following table of supplies has been prepared with considerable care from actual experience:—

Rations Required for Three Men, One Month.

Rations.	Pounds.	Amount in percentage of the flour.*
Flour, biscuit or crackers, rice, grits or oatmeal, but at least ¾ self-raising flour (equal to 1⅓ lbs. per man, per day)	125	1.
Extra heavy clear mess pork about ¾; pickled ham, say ¼	82	.650
Beans or peas	20	.160
Sugar (coffee A)	18	.140
Tea (good young Hyson)	3	.024
Dried apples	10	.080
Cheese	4	.032
Salt	2	.016
Pepper	¼	.002
Baking powder (Durkee's or Royal), if self-raising flour is not used	2½	.020
Equal to $2\frac{85}{100}$ lbs. per man per day, or total	266¾ lbs.	

* Supplies purchased in the proportions given in this column should come out even.

Equipment.—A shelter or bake-oven tent is preferable, although a closed A tent is often used in "fly time" (June and July): the former is more cheerful, healthier and warmer, because it lets the fire shine in. The style sketched will hold three men with supplies: it requires 12 yards of cotton drilling, 36 inches wide.

FIG. 13.

Explorers' bake-oven tent.

Two light explorer's axes, weighing with handles 2¾ lbs. for summer use and 5 lbs. for winter, each, are needed; if the exploration is for mineral, the backs or poles should be of steel. For three men a nest of two or three oval tin pails with covers, the largest holding 5 quarts, one frying-pan with socket handle, one 2 or 3 quart tin basin, one large spoon, one butcher or sheath knife, and a tin cup, plate, knife, fork and spoon to each man in the party, is all that is required.

If the party be large, a tin bake-oven will pay; it should be hinged so as to fold up. Canoes have already been mentioned: they are best for most kinds of river and lake service on account of their lightness, which makes them easy to portage, the ease with which they can be repaired with canvas and pitch (or resin and pork fat), and their suitableness for running rapids. But sometimes they

NOTE.—The stools shown in Fig. 13 do not belong to a camp outfit. They were introduced inadvertently by the engraver.

cannot be procured, and in low water are more liable to injury from rocks than are boats; a skiff 2½ fathoms long, pointed at both ends, with flaring sides, and made of ½ inch boards, is a good substitute. Each man in the party should have a pocket compass, water-proof match box, and sheath knife, and there should be at least one leather and one tin map case in each party. Should the exploration be for minerals, a dip compass, and at least one exploring pick ought to be added. A small shovel will pay in such a party, but is seldom carried. A dial compass for use in traveling when there is local attraction, or in discovering the same, is often advantageous. I have found a small horse-shoe magnet and a pocket lens useful. Every party going in the woods should be supplied with the best maps that can be procured (Farmer's are the best I have seen), and always with exact tracings of the U. S. Land Office plats or maps of the Townships they propose visiting; these plats can be obtained at any U. S. Land Office and cost, if they show variations of the needle and geological notes, about $2.25 each at Marquette. The following are the locations of all the U. S. Land Offices in Michigan, with names of officers.

U. S. Land Offices in Michigan.

District.	Office.	Register.	Receiver.
Detroit	Detroit	F. Morley	J. M. Farland.
East Saginaw	East Saginaw	Wm. R. Bates	A. A. Day.
Ionia	Ionia	J. H. Kidd	J. C. Jennings.
Traverse City	Traverse City	Morgan Bates	Perry Hanna.
Marquette	Marquette	A. Campbell	J. M. Wilkinson.

The explorer cannot too carefully study his maps; next to personal examination in the field they are his great original sources of information. The surveys of the Upper Peninsula, as is explained in Chapter I., were made with great care, and embrace topography, timber, soil and geology.

Under sundries which will be found useful in camp, may be mentioned: Soap and towels, thread and needles, buttons, awl, strong twine, some cotton cloth, a file to sharpen axes, a few wrought nails if a boat is used, some extra pairs of moose-skin moccasins (for summer), fish-lines and hooks, extra compass, resin or pitch, blank U. S. plats, and fly-nets or "fly-medicine," or

both in "fly-time." A large, stout, water-proof, tin match-box, extra note-book and pencils, paper and envelopes, are desirable. A short, light, single-barreled shot-gun, with bore large enough to chamber buck-shot, may be carried to advantage after the middle of August.

Mode of Working.—Mineral explorations, and especially those for iron, will only be considered under this head. The leading idea is, of course, to make a systematic and exhaustive examination of the surface for the mineral sought: to this end all outcrops of rock of whatever kind, and all boulders must be examined for some "sign" or "show" of mineral. As has been elsewhere remarked, the upturned roots of trees afford one of the best sources of information: the beds of rapid streams, which usually contain boulders and often expose the solid ledge, should be carefully examined. Any indication at all favorable should be followed up by digging. Next in importance to this kind of search is the use of the magnetic needle in discovering local attractions due to iron-ore; it is safe to assume that more than one-half the iron in the Lake Superior iron region is sufficiently magnetic to produce appreciable variations in an ordinary compass; and as magnetic ore will attract the needle at the same distance with equal strength when covered by rock, earth, air or water, this instrument is of great service to the explorer. Its use is fully considered elsewhere, as well as the geological principles applicable to this kind of work.

An explorer should make a careful sketch or map of each section examined, on a scale of 4 inches to 1 mile: on such a scale "a 40" is one inch square. On this should be marked in their proper places all streams, lakes, swamps, hills, etc., and all outcrops, with a name or sign indicating the kind of rock; colored pencils are convenient for delineating the different varieties of rocks. Opposite each such sketch should be a full written description of the rocks and minerals found, as well as notes on timber and soil.

The accompanying sketch (Fig. 14) of Sec. 29, T. 50, R. 30, from the note-book of the late A. M. Brotherton, a perfectly honest and thoroughly competent explorer, will serve as an illustration. To it is appended a map of the same section (Fig. 15), from the U. S. Surveys, which shows, valuable as these surveys are, and reliable, so far as the section lines go, they often are considerably in error in their representations of the interior of sections.

Fig. 14. Sec. 29, T. 50, R. 30. Explorer's Sketch.

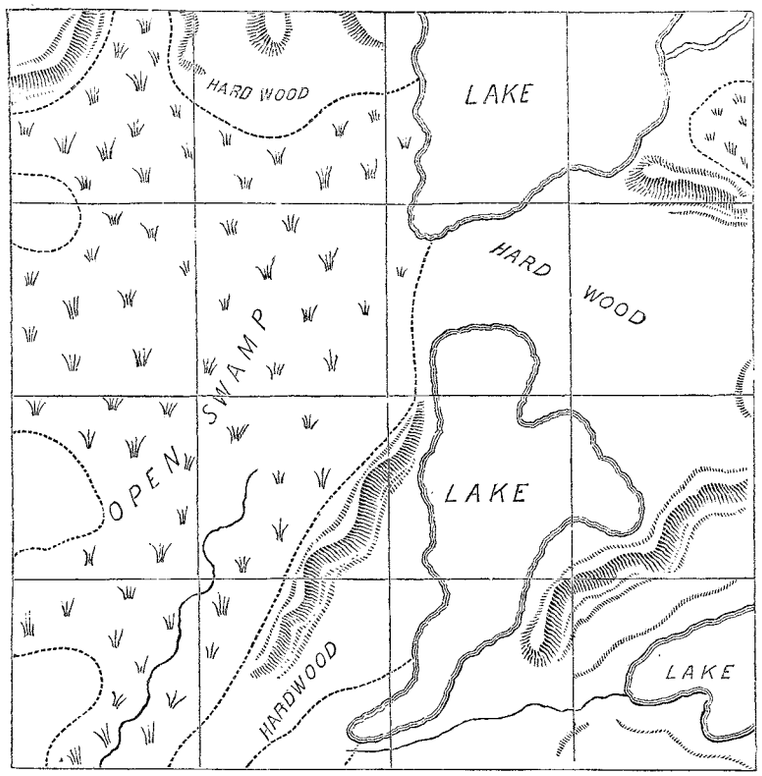
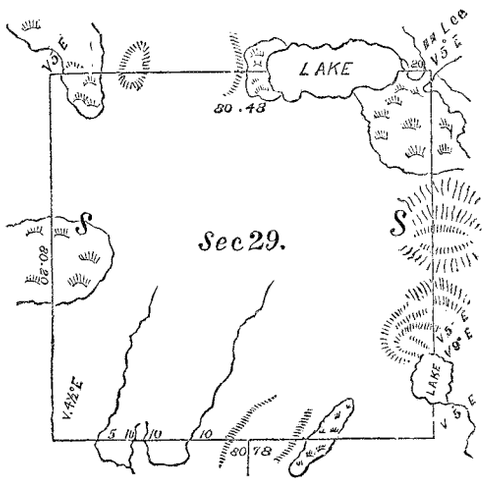


Fig. 15. Same Section, from U. S. Linear Surveys.



How to Recognize Iron Ores.—As a large majority of the explorers now employed are timber-hunters, they need not necessarily have a knowledge of minerals. I have, however, generally found these men more or less interested in rocks, and often very desirous of knowing how to determine the more common ores, so as to be able to note any they might find. To obtain a good knowledge, the study of a complete collection, or a residence at a mine, is indispensable. A few brief characteristics, only, will here be given, by which explorers may generally recognize iron ores in the woods.—First.—They are considerably *heavier* than any other rocks with which they are associated. Rich, magnetic, and specular ores, like those of the Marquette region, are nearly twice as heavy as the same bulk of the more common rocks, and five-sevenths as heavy as a piece of iron or steel of the same size. The soft hematites are much lighter, but are still appreciably heavier than the heaviest rock. As fine muscular sense and much practice are necessary in this business, the inexperienced explorer is advised, in every instance, to break pieces of rock of the same size as the supposed ore specimen, when, by lifting them together and changing from one hand to the other, the difference in weight will at once be felt if one of the specimens be iron ore. If the explorer is provided with a pair of balances, as is explained hereafter, he may determine, not only as to whether the substance is iron ore or not, but also approximately the percentage of metallic iron.—Second.—As to color, *magnetic* ores are black, and when pounded with the axe give a black powder, which will adhere to the axe or pick. Red *specular* ores are often bright and shining on their weathered surface, almost like polished steel; they give a red powder when pulverized, which does not adhere to the axe. Soft *hematite* ores are reddish and brownish in color, are generally porous, and often soft and earthy, in character; when pulverized they give a brownish and sometimes a yellowish powder, which does not adhere to iron or steel. These characteristics are possessed by none of the rocks of the Marquette region.—Third. Magnetic ores attract the needle of the compass strongly, often causing the north end to point south. Other ores and rocks do not attract it, but a little magnetic ore is often disseminated through rocks, especially greenstone, thereby producing more or less variation of the needle, which may not indicate valuable ores.

The rock which is oftenest mistaken for iron ore is Hornblende, and the related Diorites or Greenstones. These rocks are heavy and dark colored, and often contain enough magnetite to give them some influence on the needle. Many an explorer has carried heavy pieces of this rock many miles through the woods, only to throw them away in disgust on meeting some one who had, perhaps, only so much knowledge of ores, as it is expected these few facts will impart. Some have persisted in their folly, and bought lands on which experienced iron explorers could only find hornblendic rock. This rock differs from the ore, which it most resembles, in being *lighter*, and in giving a *light colored powder*, which does not adhere to iron or steel, as well as in other less important particulars, as may be seen by comparing the two, which should be done.

The text relating to the magnetism of rocks and use of the needle in finding ore might properly have been inserted here as a division under Exploration, of which subject it forms properly a part. But the amount of material which had been prepared on that subject, and other reasons, determined me to place it in a distinct chapter (VIII.), which follows.

3. Digging for Ore.

The exploration work above described is superficial, and will not usually determine whether a certain piece of land contains workable deposits of ore or not. Such examinations are usually made to determine whether lands are worth buying at government price, or as preliminary to a more thorough exploration. When we consider that soft hematite ores never outcrop, and that pure hard ores rarely do, it is evident that something more than looking over the surface is necessary. The excavations of earth and rock required in an exhaustive exploration of a piece of land are mining operations, and will be considered in another chapter. Only a few points will be presented here which bear especially on work of this kind.

This work is simply sinking test-pits and shafts, and opening trenches (costeaning) and drifts to expose the solid ledge. It rarely happens that such work need be prosecuted into the solid ledge. As has been before remarked, if there be pure ore at the locality, i