The finer granular quartz is sometimes accompanied by more or less unchanged chert.

Garnets, usually under 1^{mm} in diameter, and usually pale yellow, brown or reddish, are frequently found in some beds. Occasionally beds are found containing garnets up to 4^{mm} or larger and making up more than 10% by volume of the bed. Small amounts of chlorite and either light or dark mica are found in some beds.

In types (4a) and (4b) the "grünerite" is subordinate in amount to the magnetite and granular quartz, and is more commonly in imperfect rosettes. There is apt to be more or less fine specular hematite in type (4a). Type (4c) differs from (4a) in that the "grünerite" is usually in small, well developed rosettes and there may be more granular chert present.

(5) Jaspilite.

Chert, commonly colored red, and specular hematite in alternate bands from less than 0.1^{mm} to more than 2^{mm} in thickness. Appreciable quantities of fine magnetite are usually disseminated in the hematite bands.

The chert appears fragmental in some of the bands in many localities, either because of an original granular character due to greenalitic material, or from some mechanical cause.

The hematite varies from very fine specular with subordinate fine, disseminated magnetite, to the types with hematite scales over 1^{mm} in diameter and with coarser and more abundant magnetite.

East of Champion, practically all gradations between (3) and (5) were seen, while west of Michigamme the types from

(5) to (6) were more common, the more intensive metamorphism apparently having converted most of the hematite of the jaspilite into magnetite and caused the recrystallization of much of the chert into granular quartz. No sharp line of division could be drawn between type (5), (Jaspilite) and type (6) closely resembling type (4) but lacking the "grünerite". The granular quartz layers in some places were "sugary" and loosely coherent with occasionally some chert remaining. In other places the interlocking granular quartz gave the rock the appearance of a highly ferruginous quartzite.

(6a) This type differs from (6) mainly in that the magnetite (and hematite) is also usually more granular in appearance than (6), resulting in the entire rock being usually more sandy in character.

(7) "Greenalite".

The term "greenalite" is used in this work, especially in the field, for three or more substances, each seemingly a hydrous ferrous silicate containing considerable iron. Included were varying amounts of a fine scaly mineral, a fine fibrous mineral and an earthy material with a more or less granular or oölitic character to the aggregate. Under a strong hand lens the oölitic character was often less apparent than to the unaided eye. These three or more substances were generally pale in color with greenish tinges predominant.

The greenalitic material occurs abundantly in some places, especially near the base of the iron formation, in beds, lenses and disseminated through some of the sideritic layers.

(8) The greenalitic material rusts upon exposure and seems to weather to a somewhat sandy appearing, loosely coherent aggregate of "limonite", or earthy hematite, through which is disseminated abundant small, somewhat granular particles of chert or quartz.

(9) The term "taconyte" is frequently loosely used for some of the phases of the iron formations, especially for the types (4), (6) and (8).

All of the phases of the iron formation as listed above were seen in various stages of alteration, up to and including soft earthy siliceous "limonite" or hematite and ferruginous quartz and chert.

The magnetite is commonly altered, partly or entirely, to hematite ("martite") and in many instances to "limonite". Much of the chert or granular quartz in many cases has been dissolved out and deposited in cavities and seams as quartz crystals. These are frequently double terminated and may be of any size up to several millimeters and in any color as well as colorless and black.

The term "limonite" as here used includes what is probably very fine göthite as well as an earthy or colloidal iron hydrate. Coarse göthite, in crystals up to several millimeters in length are abundant in much of the altered iron formation.

The following minerals were found in the Negaunee iron formation at the Champion Mine. The majority of them were also found at the Spurr and Michigamme Mines.

Graphite, - in grüneritic phases of the iron formation.

Pyrrhotite, - rare. In small amounts with chalcopyrite.

Chalcopyrite, - $CuFeS_2$. In veinlets and disseminated. Also, rarely, in sphenoids to 3^{mm}.

Pyrite, - FeS_2. Very abundant, sometimes in masses of over 100 pounds. In crystals and also coarsely granular with magnetite.

Marcasite, - FeS_2. Not abundant. Seems to disintegrate more rapidly on the dumps than does pyrite.

Quartz, - SiO_2. (Described above).

Chalcedony, - Chert, jasper, etc. (Described above).

Hematite, - Fe_2O_3. Besides the earthy and specular as described above, quite a number of thick, broad plates up to 3 inches across were found in veins. "Martite" (hematite pseudomorph after magnetite) is abundant. Octahedrons to several millimeters.

Magnetite, - Fe_3O_4. In octahedrons up to 6^{mm} as well as coarse to microscopically fine.

Pyrolusite or other manganese oxide, altered from manganite.

Manganite, - Mno (OH). In crystals, especially with barite. Not abundant.

Göthite and "limonite". Fe_2O_3. (NOH) Described above.

Calcite, - $CaCO_3$. Crystals of various habits and size, also coarse to fine cleavable. In veins and cavities.

Dolomite, - (CaMg) CO_3. Rhombs and granular cleavable in seams and cavities.

Ankerite, - (CaMgFe) CO_3. An original constituent of the iron formation, but all that was found in the Negaunee iron formation was in veins and cavities. Small rhombs and coarsely cleavable.

Siderite, - $FeCO_3$. Also a common original constituent of the iron formation, but found here only in veins. In rhombs up to 3 inches across. Also coarsely to finely cleavable.

Rhodochrosite, - $MnCO_3$. In veins and vugs in the ore and iron formation. Usually small crystals and granularly cleavable.

Adularia, - $KAlSi_3O_8$.	A potash feldspar in small, pale and often transparent crystals in seams and cavities. Crystals show prominent m and c faces. Up to 3^{mm}.
Cummingtonite, Grunerite, etc.	Amphibole high in iron, low in alumina and with or without Mg, etc. Fibrous to prismatic. Described above.
Garnet, - Sil. of Mg, Fe, etc.	Minute traps and dodecs to some 6^{mm} in diameter. Pale colors, generally brownish to reddish. Large reddish to blackish dodeca hedrons that measured up to 4 inches across the flats were found along the edges of basic dikes, but not in the iron formation itself.
Chlorite, - Hyd. Mg. Al, silicate.	Minute plates disseminated rather sparingly through some beds of the iron formation. Large plates of Clinochlore and considerable chlorite of other types were found in veins in the iron formation but not derived from it.
"Sericite", - Hyd. Sil. of K (or Na) and Al.	Fine clay like to scaly material 1^{mm} in diameter. In veins and cavities.
Apatite, - Phosphate of Ca, etc.	Crystals up to 2 or 3^{mm} in vugs and seams, especially in the ore. Crystals prismatic to tabular. Apprently the chief source of Phosphorus in the ore.
Barite, - $BaSO_4$.	In seams and vugs in the iron formation and in the ore. In parallel plates and rosettes. Insoluble form of sulphur in the ore.
Anhydrite, - $CaSO_4$.	In seams and cavities. Not abundant but probably less rare than gypsum.
Gypsum, - $CaSO_4 \cdot 2H_2O$.	In scales and plates disseminated through the ore and in seams and cavities. Also in broad plates sometimes found several inches across.
Melanterite, - $FeSO_4 \cdot 7H_2O$.	As an alteration product of pyrite.

The following minerals were also found at the Champion Mine, but not intimately associated with the ore or the iron formation.

Molybdenite, - MoS_2.	In thin to thick cleavage plates up to 15^{mm} in diameter. In pegmatites and in or near basic dikes that cut the iron formation. Associated with black tourmaline, large dark red garnet, chloritoid, quartz, pyrite, chalcopyrite and clinochlore.

Microcline, $KAlSi_3O_8$.) Albite, - $NaAlSi_3O_8$.)	In small to large plates in pegmatites that cut the iron formation.
Calcic Feldspar, - Sil. of Ca,Na,Al.	Up to several inches to length. Usually less than 5[mm] long. Some tabular parallel to b and others tabular parallel to c. In basic dikes cutting the iron formation.
Augite, - Sil. of Ca, Mg, Fe, Al.	In basic dikes cutting the iron formation. Mostly altered to uralite (an amphibole).
Uralite, - Sil of Mg, Fe, Al.	Usually makes up about half the volume of the Clarksburg intrusives into the iron formation. Some specimens show uralite several inches in length. Because of its pseudomorphous origin (after augite usually) it is more fibrous than hornblende and not usually as dark. Usually accompanied by fine but visible disseminated pyrite and more or less carbonate and sericite.
Hornblende, - Sil.of Ca,Mg,Fe,Al.) Actinolite, - Sil.of Ca,Mg,Fe.)	Amphiboles found in some of the schistose and gneissoid rocks in the foot of the iron formation.
Beryl, - Be,Al,Sil.	In small pale greenish to bluish green crystals with quartz, muscovite, andalusite and green apatite in feldspar-poor pegmatites cutting the iron formation.
Andalusite, - Al_2SiO_5.	Pale lilac to nearly colorless crystals and cleavage masses in feldspar-poor pegmatites. (See under Beryl).
Epidote, - Sil,Ca,Fe, Al.	Mostly fine granular. Disseminated through or in seams in basic dikes cutting the iron formation.
Tourmaline, - Boro-sil. of Mg,Fe,Al,etc.	In black crystals, ranging from very fine bundles of parallel needles to stellate groups and individual crystals up to 10 or 15[mm] in diameter. In quartz veins and feldspar-poor pegmatites. Also with large garnet dodecs and chlorite and "martite" in sheared and altered basic dikes near the edges. Also with chloritoid in sericitic schist derived from slaty phases in and near the base of the Goodrich.
Clinochlore,-Hyd. Sil. of Mg, (Fe), Al.	In plates up to 15[mm] in veins with molybdenite (q.v.) and other minerals in veins. Also in some of the schists in the foot of the iron formation. Also observed frequently in the nearby Clarksburg tuff.

Aphrosiderite,- Hy. Sil,Mg,Fe,Al.	A term applied to the very fine scaly to almost earthy alteration of many of the basic dikes cutting the iron formation. This chloritic material forms most of the matrix for the large dark brownish red garnets (up to 4 inches in diameter) that are so abundant in this area. The garnets are not generally altered to chlorite as is often believed, but are imbedded in the chlorite, and associated with scattered octs of magnetite in various stages in their alteration to hematite ("martite") and frequently with long radiated tufts of cummingtonite or other pale colored iron bearing amphibole.
Muscovite, - potash mica.	Plates up to 25^{mm} in pegmatite dikes that cut the iron formation. Also in smaller scales in the gneisses and some of the schists in the foot of the iron formation.
Sericite,-potash mica.	The term sericite is used rather loosely in the field for very fine light colored mica and may include paragonite. Developed from feldspar in the altered dike rocks. Abundant, and sometimes the principle constituent of the fine mica schists developed from slaty phases of the Goodrich and older sediments. Also very abundant in the granitized sediments in the foot of the iron formation.
Chloritoid,-Hyd. Sil, Mg, Fe,Al.	While most of the chloritoid from the Lake Michigamme area is usually referred to masonite, much of it may be some other chloritoid as comparatively little of it has been tested. There are two distinct methods of occurrence, - 1), In plates commonly up to 1 inch in diameter and frequently found in plates more than 2 inches across, in a slaty or sericitic phase of the Goodrich conglomerate or a slate immediately below it. 2), in broad plates in altered basic dikes with tourmaline, garnet, chlorite and "martite".
Apatite,-Phos. of Ca, etc.	Besides the occurrence already mentioned as small transparent to reddish crystals in the iron formation and ore, apatite also occurs in greenish prismatic crystals up to 3 inches in length and an inch in diameter in some of the feldspar-poor pegmatites that cut the iron formation.

The iron formation does not seem to vary a great deal in original iron content throughout most of its thickness, but does vary markedly in mineralogical composition in most sections across it due to the difference in metamorphism. The lower part of the iron formation is apt to be cherty siderite or "greenalite" except where metamorphosed to grüneritic material. The upper, oxidized portion may vary from 0 to more than 50% of the thickness, usually being deepest in those areas where the formation is less highly metamorphosed but was disturbed enough to have been sufficiently elevated and broken to permit of more rapid and deeper oxidation.

In many localities the iron formation quite near the base is quite well oxidized, perhaps due to fracturing that permitted ready alteration previous to the time when so much of the formation was subjected to great metamorphosing influences.

GOODRICH

The Goodrich conglomerate rests either directly upon the Negaunee iron formation or else upon what was a thin emergence slate that may have been deposited upon the iron formation in those parts of the area where the iron sea became shallower, but the sea bottom did not emerge, during the upheaval that accompanied the Ishpeming volcanic action farther to the east. Where the Goodrich lies across the seemingly rather gentle pre-Goodrich anticlines of the iron formation, the erosion does not appear to be deep in any place and the thickness of the underlying iron formation does not seem to be appreciably diminished.

In no place was any evidence found that the iron formation had been deeply eroded before the Goodrich was deposited. The deepest erosion apparently took place where anticlines of the iron formation, especially those that were faulted and overthrust, presented conditions favorable to relatively deep and rapid, but local, erosion.

There are some localities where the Goodrich seems to lie directly upon pre-Negaunee rocks but this is generally interpreted as an overlap, the comparatively gently rolling iron formation having been locally depressed at the time of the Ishpeming volcanics, partly compensating for its elevation in other parts of the area, with the Goodrich-Bijiki sea locally advancing farther than the shore line of the previous Negaunee sea. In at least one place north of Champion, the Goodrich appears to lie directly upon the Kitchi, but this appears to be because of faulting. This faulting is strongly suggested by the structure of the iron formation as mapped by magnetic work north of the Pascoe pit, and had also been previously indicated by mapping in the foot-wall rocks northwest of there.

There is a considerable stretch of territory along the south limb of the iron bearing series, both east and west of Champion, where the Negaunee iron formation has been previously mapped as having been completely eroded, but the dip needle mapping shows that it continues through these stretches with apparently undiminished thickness.

Where the Goodrich conglomerate does not rest directly upon the Negaunee iron formation, there is apt to be considerable slaty material (or mica schist) in the conglomerate. Locally there may be so much of this material in the Goodrich that the subordinate amount of chert, jasper and other material from the iron formation is rather inconspicuous.

Slaty or mica schist beds in or just below the Goodrich conglomerate are apt to have an abundance of chloritoid developed. This is particularly noticeable along the south limb in some places as just south and southeast of Champion where the chloritoid plates are frequently found more than an inch in diameter.

Above the Goodrich conglomerate there is usually found a considerable thickness of quartzite, which is white and vitreous in some places but almost black in others. This quartzite seems to be thicker on the north limb where it has a width of 35 to 40 paces (dip about 60° southward) in an open cross-cut at the Michigamme Mine. This would indicate a thickness of about 80 or 90 feet, but it appears to be thicker to the eastward and thinner to the south and west. Southward, farther from the main shore line, this quartzite appears to thin out considerably and to be partly replaced by graywacke and perhaps by slate. This quartzite and graywacke to the southward may have a total thickness greater than that of the quartzite alone to the northward, though the quartzite member alone may be thinner.

Above the Goodrich quartzite and graywacke there is usually a considerable thickness of slate, though this slate is generally lacking on the north limb close to the old shore line. The total thickness of the Goodrich on the north limb may be about 100 feet almost all of which is usually quartzite. Farther southward, the total thickness may be as much as 200 to 300 feet, though the average is likely to be less. Of this thickness to the southward, graywacke and slate will each probably total more than the quartzite. The apparent thickness of this Goodrich may be two or three times the amount just given, due to repetition by folding and faulting. That is, in drilling, it might be necessary to go through many of the beds two or more times for a total of 300 to more than 600 feet.

The tabulation given below which has been compiled from the evidence available in a great many exposures, each of quite limited stratigraphic range, is probably fairly close to a representative succession of the Goodrich where not too close to the north limb of the basin.

7)	Slate, usually quite graphitic and in many places more of a slaty graphite, with a few thin beds of dark graywacke. The graphite is microscopically fine.	20 to 60 feet.
6)	Slaty graywacke, with thin beds of coarser graywacke and a few thin slate beds	10 to 100 feet.

5)	Mottled slate and thin bedded graywacke	5 to 15 feet.
4)	Slaty graywacke, similar to 6 (which may be a fault repetition of it, 3 and 4)	10 to 50 feet.
3)	Graywacke with subordinate beds of quartzite and a little slate	20 to 50 feet.
2)	Quartzite with some graywacke	50 to 100 feet.
1)	Conglomerate	1 to 10 feet.
	Total, -	200 feet (±)

BIJIKI IRON FORMATION

The Bijiki iron formation is not well exposed along the north limb of the basin but outcrops frequently and for considerable distances along the southern limb in Section 36 (48-30) and again in Sections 4 and 5 (T. 47 N., R. 29 W.) southeast of Champion. There are also abundant exposures of it throughout much of the central and north central portions of the trough.

At the Michigamme Mine the Bijiki lies directly and conformably upon the Goodrich quartzite with no slate or graywacke between. The mapping indicates that this relation may hold in general along the north limb, close to the original shore line. A little farther south it lies upon graywacke or slate which appears to thicken to the southward. The foot-wall slate is usually more or less graphitic.

In the central part of the trough the Bijiki is usually found intricately folded or crumpled and the formation could be followed only by the most careful and detailed mapping.

The Bijiki iron formation is much thinner than the Negaunee. Measured thickness are difficult to obtain because of the intricate folding and faulting and also because seldom were both the foot and hanging formations exposed in the outcrops. The mapping indicated that the thickness was almost certainly not less than 30 feet nor more than 150 feet and it is believed that a thickness of about 50 feet is fairly representative, from which it can be seen that with the prevalent folding and faulting, the distance through it can be expected to vary between 60 and 150 feet.

The Bijiki is not only thinner than the Negaunee but in many places is somewhat leaner. One indication of this leaner character is to be seen in the greater abundance of an iron carbonate lighter in weight than siderite and apparently nearer to ankerite.

In general character the Bijiki is very similar to the Negaunee iron formation but more specimens were obtained that showed abundant small garnets, graphite and chloritic material than in the older, thicker Negaunee. A number of outcrops, especially in Section 5 (T. 47 N., R. 29 W) showed abundant cherty iron carbonate in various stages of recrystallization, even near the top of the formation. Much more of the Bijiki, though, has been metamorphosed to a grüneritic phase and a good deal of it is limonitic. Considerable of the limonitic type is an alteration of the grüneritic phase as shown by specimens from the Webster, Beaufort and other mines. Much of the ore at the Imperial, Webster, Portland, Beaufort and other mines were derived from the grüneritic phase, the "grünerite" having weathered to "limonite" and the magnetite to hematite and "limonite". The granular quartz beds were partly dissolved out with often an abundance of quartz crystals forming in veins and cavities. The result was a considerable amount of low grade siliceous limonitic ore. The same alteration of grüneritic rock to lean siliceous "limonite" was also noted in 1944 on Section 12 (T. 47 N., R. 31 W.) where such alteration was then thought to be a local condition, not generally prevalent in the area.

The graphite, often seen in fairly large amounts intermingled with the "grünerite", magnetite and granular quartz, is very unequally distributed through the formation, both across the strike and along it. It seems most abundant where the footwall slates are also high in graphite, and as there is no evidence that the iron formation and the slates were rich in organic material in those places, it seems likely that the graphite may have been derived from the dis-association of the iron carbonates originally present. Enough finely disseminated magnetite is frequently present in the graphite slates to permit them to be followed quite readily in the magnetic mapping.

The Bijiki shows little or none of the jaspilitic phases and very little of the magnetite-granular quartz phase that lacks "grünerite", which are found in the Negaunee in the same areas. This difference may be due to there having been little if any appreciable amount or depth of oxidation in the Bijiki before it was metamorphosed. The character of the hanging-wall formations and their relations to the Bijiki indicate that there was probably no emergence of the Bijiki before the next formation was laid down and hence less chance of its becoming oxidized. As previously states, some considerable amount of the weathering in the Bijiki that has resulted in the familiar limonitic phase, took place after the cherty iron carbonate had been metamorphosed to grüneritic material.

The deposition of the Bijiki was stopped by violent and wide spread volcanic activity near Lake Michigamme and in the area immediately to the eastward. Depending upon the amount of the uplift occasioned by, proximity to and direction from the volcanic activity, the Bijiki was (1), considerably elevated and subjected to weathering and erosion; (2), succeeded by clastic sediments, especially a slaty formation; or (3), had basic volcanic matter embedded directly in its top layers.

Condition (1), though not easy to prove, was indicated as a probability in small areas near Champion, such as near the Dalliba Mine, where much of the upper part of the Bijiki consists of interbedded limonitic chert, with no evidence that any later pre-Cambrian formations had been deposited and consolidated upon it.

Condition (2), was probably prevalent over most of the area west of the Peshekee River and in some of the area north of Champion and probably in much of the other nearby areas of Bijiki.

Condition (3), prevailed in the immediate vicinity of Champion and to the eastward for at least a mile or more. In Section 5 (T. 47 N., R. 29 W.) the Bijiki does not appear to have emerged from the sea at the close of the Bijiki as the practically unoxidized phase shows occasional large, unsorted fragments of basic material partly embedded in its top layers and abundant basic ash deposited directly upon it.

The intricate folding of the Bijiki in the central part of the trough is apparent even on the small scale Key Map (Plate I), especially in Sections 29, 30, 31 and 32 (T. 48 N., R. 29 W.) north of Champion. The belt of Bijiki shown was followed practically every foot of the way from where it outcrops near the mouth of the Peshekee River (from which it takes its name) near the center of Section 25 (T. 48 N., R. 30 W.), across Section 30 and most of Section 29, where it was found to turn sharply back, as shown in the Key Map, to near the south 1/4 post of Section 30, 48-29. Near the south 1/4 post of Section 30, the Bijiki forms a crumpled anticline from which the formation continues back eastward and south-eastward, still dipping steeply southward, to east of the center of Section 32 where it again bends sharply and continues back westward to

Champion. Near the west line of Section 32, the formation again is folded sharply and was followed back eastward for about one-half a mile to where it was apparently displaced by a fault. In Champion, in the SW$\frac{1}{4}$ of Section 32, The Bijiki forms a syncline, overlain by crumpled Clarksburg tuff, and reappears, dipping northward, near the south line of the section.

In a Michigan Geological Survey map, dated 1930, most of the portion of this belt just described is properly designated as Bijiki, but that part of it south of Champion is labeled "Greenwood". Also, on the same 1930 Survey map, in the north half of Section 29, the southern part of the belt shown there is called Bijiki, but the continuation of the belt which bends sharply back eastward near the west line of Section 29 is shown as an independent parallel belt and was classified as "Greenwood" formation, an iron formation that was believed to lie between the Negaunee and Bijiki iron formations. No evidence of the "Greenwood Iron Formation" was found during this survey and the occurrences of it noted on the 1930 map were either (1) traced directly into what the same map called Bijiki, or (2) traced into the Negaunee iron formation, or (3) were not found. In the area covered by the map of 1930 the strata within the synclinal trough are very much contorted and it was only by extremely detailed magnetic work that the absence of the "Greenwood" formation was shown in this area.

CLARKSBURG

The Clarksburg tuff in some places, as in Section 4 (T. 48 N., R. 29 W.), lies directly upon unoxidized cherty iron carbonate of the Bijiki iron formation. In other localities it lies upon the emergence slate above the Bijiki, and nearer to the north side of the trough it lies close upon oxidized Bijiki and it is probable that still nearer to the old local shore line there may be fine ash mingled with the Goodrich where the latter, being close to the local shore, would be later than the Goodrich deposited earlier when the local shore line was farther to the south.

The Clarksburg tuff appears coarsest and thickest in the vicinity of Champion and eastward, and in the central and southern part of the trough. Close southeast of Champion the tuff has an exposed width of about 150 paces. This width is apparently somewhat more than half way across the crumpled syncline and the thickness of the tuff is probably between 150 and 400 feet. Farther to the eastward it appears to be appreciably thicker, but is probably less than 1,000 feet in general.

On some of the islands in Lake Michigamme it is comparatively thin, there being usually several beds of coarse tuff, each from 1 to 10 feet in thickness, and several beds of tuffaceous graywacke perhaps totalling 30 feet. The total thickness of tuff and tuffaceous material near the west shore of Lake Michigamme is probably near 50 feet and it probably thins out rather rapidly farther westward.

The Clarksburg tuff generally consists of abundant fragments of basic igneous material, much of it now altered to dark amphibole, with many fragments of quartzite, iron formation, gneisses and schists from older formations in a matrix of basic ash and graywacke. Near Champion many of the fragments are several feet in diameter but the size of the fragments diminishes rapidly in all directions from there. Four miles to the westward, on islands in Lake Michigamme, it was rare to find fragments more than a few inches in diameter, and four or five miles to the eastward from Champion most of the fragments are still smaller.

In some few limited areas, presumably where the volcanic fragments fell into shallow water, there is considerable conglomeratic material at or near the base of the Clarksburg.

Clarksburg dikes and sills are abundant throughout the area, several of them having a thickness of more than 100 feet. The material was a diabase or gabbro, now quite thoroughly uralitized. Representative specimens from various localities show dark greenish black uralite (altered from a pyroxene, usually augite) in various sizes up to more than 50^{mm} in length; calcic feldspar, some tabular parallel to b and some tabular parallel to c; subordinate mica, mostly near biotite; chloritic material, from fine earthy to plates several millimeters across and almost always visible, disseminated pyrite. Secondary quartz, often quite bluish is frequently present in considerable amount. Pyrrhotite, chalcopyrite and occasionally pentlandite were seen, but only along or near shear zones.

The dikes strike about east and west with varying dips. Some are vertical and others dip at varying angles with many of them so nearly the dip of the intruded beds that it was difficult to tell whether they were dikes or sills.

Where the dikes and sills cut the iron formations, the more nearly vertical dikes, even where no contacts were available could often be distinguished from the sills and the dikes nearly parallel to the bedding by the dip needle readings. The more nearly vertical dikes usually gave low readings ($-1°$ to $+2°$), while the others often gave quite high readings attributed to the underlying iron formation, as no appreciable amount of magnetic minerals could be detected in the intrusions themselves.

Volcanic necks and plugs were not positively identified as most of the field work consisted of tracing, mapping and correlating the iron formations. It was suspected that certain exposures of coarse uralitized gabbro and related rocks near the east side of Lake Michigamme, and the coarse uralitized gabbro between the center and the east 1/4 post of Section 31 (T. 48 N., R. 29 W.) may have been volcanic plugs. Several roughly oval areas, devoid of outcrops, giving very low magnetic readings and surrounded by crumpled belts of iron formation that give quite high readings are also suspected of being volcanic plugs or vents. One such area is just southeast of the Michigamme cemetery. It is roughly crescent shaped, convex to the north, about 300 feet long east and west and about 150 feet wide. It is surrounded by crumpled belts of iron formation, giving very high readings, with the belts stopping abruptly at the margin of the area of very low readings. The Bijiki iron formation outcropped in the vicinity and was badly faulted and crumpled.

The principal Clarksburg volcanic vent (or vents) will probably be found near the south side of the trough and within two miles of Champion.

MICHIGAMME

The Clarksburg tuff grades rapidly into the overlying graywackes and slates that are usually mapped as Michigamme. The tuff thins out rapidly to the westward and is replaced by generally thick graywackes and slates containing a great deal of basic ash in some layers. The lower part of the graywacke is quite conglomeratic in places. The coarse graywacke grades up through a finer and generally concretionary graywacke into slate. The slate also has much fine basic ash in several horizons, especially near the base. It is not certain that all of the ash came directly from the volcanic vents as it seems likely that ash falling on the nearby shore to the northward might be washed down into the shallow water deposits for a long time after the volcanic activity had ceased.

The concretions in the graywacke are commonly several inches in diameter and usually elliptical in cross-section with the shortest dimension from north to south perpendicular to the nearly vertical cleavage in the graywacke. The longest dimension of the concretions is almost invariably down the dip of the cleavage. These quartzitic concretions are often solid and usually differ from the matrix in having less mica or chlorite. Some of them have a small hollow center, now lined with imperfectly developed quartz crystals and occasionally pyrite.

Between this concretionary zone, which is only a few feet thick, and the overlying mica schist and slate, is usually a belt from 5 to 30 feet thick in which are abundant x-twinned staurolites between 5 and 30 millimeters in length. Small reddish garnets also may be locally abundant.

The mica schist above the staurolitic belt grades up, through mica schist with less basic material (probably from fine basic volcanic ash) into more nearly pure mica schist and finally to slate.

It is possible that there are two belts of concretionary graywacke each overlain by staurolitic schist, but so far as was determined in the field, it was the same belt of each that so frequently re-appeared on the various islands near the west side of Lake Michigamme. In most instances the folding was obvious and the structure comprised a series of synclines and anticlines with both limbs usually dipping in the same direction. In some cases, where the concretionary graywacke and the staurolitic schist appeared in the same order on adjacent islands it was not determined whether one limb of a fold had been missed, or if there were a fault between, or if there were actually two similar appearing belts of each.

While the cleavage in the graywacke, schist and slate was generally nearly vertical, the bedding was often quite distinct, especially on the rocky, wave washed and ice scoured islands and the structure was not too difficult to determine. The widest area of Michigamme formations are intermittently exposed for about two miles along near the west shore of Lake Michigamme and nearby islands. The exposures consist mainly of the crests of anticlines. The thickness was not determined except that it is not less than 200 feet and is probably not more than 1,000 feet.

Many pegmatites, striking about east and west and dipping steeply, were seen cutting the various Michigamme formations. Some of the pegmatites were over 10 feet wide. Many of them are feldspar-poor and contain rather coarse green apatite and pale reddish andalusite.

SIBLEY

No formations definitely identified as Sibley were found in the Lake Michigamme area, but a series of east and west striking diabase dikes that are intrusive into the Clarksburg are believed to be of Sibley age. These dikes have the augite only partly uralitized and appear much fresher than the Clarksburg. Specimens of dikes presumed to be of Sibley age are listed as such in the stratigraphic index that precedes the petrographic descriptions of the hand specimens collected in the area.

Both lava flows and dikes of Sibley age are found a few miles to the westward in Baraga and Houghton counties. They have often been confused with the later Keweenawan, or post-Superior, lavas that predominate in the Copper Country.

SUPERIOR PEGMATITES and GRANITIZATION

Pegmatites, many of them passing into quartz veins along the strike, are abundant in the Ajibik quartzite and in the Michigamme formations. Fewer were seen in the less well exposed formations stratigraphically between these. One small pegmatite was found in a diabase dike intrusive into the Clarksburg in Section 22 (T. 48 N., R. 31 W.).

The pegmatites contain quartz, feldspar (predominantly) alkalic) and muscovite in varying amounts, and irregularly distributed. In many of the pegmatites there are areas up to several feet across that are almost entirely feldspar, often in cleavage slabs several inches in length. There are usually other areas that are predominantly quartz over several square feet of area. A few good samples of graphic granite were obtained. Many of the pegmatites contain one or more of the following minerals,- molybdenite, apatite, beryl, andalusite and tourmaline. Other minerals are either quite rare or occur in relatively insignificant amount.

The majority of the pegmatites strike about parallel to the trend of the country rock and seem most abundant near the crests of anticlines. The intruded formations adjacent to the pegmatites do not seem to be any more highly metamorphosed near, or in contact with them, than they are elsewhere. In many instances the country rock appears considerably more highly metamorphosed on the limbs of the folds at a considerable distance from the pegmatites. No evidence was seen that these pegmatites had any granitizing effect on the nearby sediments, nor was evidence found that the pegmatites and the granitization was caused by a granite intrusion. It may be that the pegmatites, the granitization and the formation of granitic appearing areas into which the bedding of the sediments gradually disappears, are all manifestations of the same processes involving the tremendous pressure, consequent heat and accompanying mineralizing vapors, of great crustal movements.

The cause of the great crustal movements may not be found in any one relatively small area as it was widespread at this time throughout the Lake Superior region and probably far beyond. Influences, perhaps extra-terrestrial, may have caused a sudden change in the rate of the earth's rotation, or in the position of the poles, to produce the tremendous amount of folding, faulting, metamorphism and telescoping of the formations over such a large area.

The folding that accompanied the Superior granitization is responsible for much of the predominant east and west strike of the formations in the Iron and Michigamme series. Many of the anticlines of Ajibik, Negaunee, Bijiki and other formations are overturned with both limbs dipping steeply to the northward. Much faulting accompanied the folding, many of the folds passing into thrust faults somewhere along their strike.

The granitized Kitchi on the north limb of the main trough seems, in places, to have been thrust up over the younger formations. The Kitchi, that had been compressed into north and south striking folds and granitized during the Champion revolution, was further granitized and squeezed from the north and south during the Superior revolution. This resulted in the previously north and south striking anticlines being further folded so that they now occur in somewhat dome like knobs, separated by deep valleys, trending east and west and connected by shorter, irregular valleys running more nearly north and south.

Numerous pegmatites were encountered in the mapping of the Kitchi sediments north of Lake Michigamme, but where no post-Mesnard formations were identified, the age of the pegmatites was usually not determined. In many places two series of pegmatites were found, one cutting the other, and in a few instances three series were seen. In some instances basic dikes that cut one series of pegmatites were found, in turn, cut by other pegmatites but in most other cases no evidence was seen to indicate whether the different series of pegmatites were widely separated as to age.

KEWEENAWAN

No Keweenawan dikes were found within the area of the iron formations but a few were found farther north. The one nearest to the iron formation was an east and west striking olivine diabase in Section 6 (T. 48 N., R. 30 W.), about three miles north of the iron formation. It was intrusive into all formations exposed in the vicinity, including the pegmatites.

A larger dike, about 10 feet wide, also striking east and west and dipping about 60° north, was seen near the Rolling Dam on the West branch of the Peshekee River in Section 28 (T. 49 N., R. 30 W.) not far from the south 1/4 post. This was a fresh, columnar olivine diabase.

GLACIAL and POST-GLACIAL

Glaciation has plucked the tops of many of the anticlines leaving them quite rough, but generally the less abrupt knobs were smoothed and are still almost devoid of soil. The material was mostly carried southward and glacial boulders up to more than 1,000 tons weight are scattered south of the outcrops over a zone several miles wide.

Many of the rather angular boulders of iron formation are upwards of 40 feet long, 20 feet wide and over 10 feet thick. Those that are partly buried gave a great deal of trouble in the mapping at times, as many of them are so deeply embedded in the surrounding gravel and soil that they closely resemble outcrops. One such boulder, lying so that the apparent strike and dip are close to what might be expected of an outcrop of the iron formation, had evidently been mistaken for ledge and a test pit had been sunk in it near the edge. It was evident that some of the small, somewhat oval areas of high magnetics that do not connect with any magnetic belts, may be due to similar boulders that are completely buried.

The glacial till is deep enough in some areas so that almost no outcrops are available. Township 47 North, Range 31 West is particularly lacking in outcrops, one magnetic belt being traced for almost three miles with only one outcrop found to indicate that the magnetic belt was due to underlying iron formation.

The glacial gravel was not generally separated in the mapping from that which was post-Glacial and much of the latter appeared to be glacial material reworked by streams and by the former lake in the area which was about twice the size of the present Lake Michigamme. There are numerous, fairly extensive beds of this reworked gravel, in some of which the gravel is over 20 feet thick. The best gravel, not contaminated with ferruginous material, appears to lie north of the northernmost limit of the iron formations. Glacial or post-Glacial gravel, where lying directly or close upon the iron formation is frequently found so well consolidated that trimmed specimens can be obtained without difficulty. There are also some sand and hardpan horizons so well consolidated that they can not well be handled with a power shovel.

Muskegs and remnants of glacial lakes and post-Glacial lakes occupy a considerable part of the are a between anticlinal ridges and knobs of Michigamme and older formations. Lake Michigamme is reported to be in the neighborhood of 100 feet deep over considerable of its area and it is likely that the water and muck in some of the muskegs and other lakes may be as deep.

Although the glaciation appears to have come mainly from the north, the north sides of knobs and ridges usually have very few outcrops, while the southern sides are frequently cliffs or steep slopes of bare rock. In some instances these southward facing cliffs are fault scarps.

ECONOMIC GEOLOGY

IRON ORE

Ore bodies have resulted from (1) mechanical concentration (especially in the base of the Goodrich conglomerate). (2) Removal of silica. (3) Addition of iron oxide. (4) Some combination of two or more of these processes.

A good example of a combination of these processes was seen at the National Mine, south of Ishpeming, where specimens were collected that showed the following stages in the formation of ore in the base of the Goodrich conglomerate. (1), Mechanical concentration of iron bearing fragments from the immediately underlying Negaunee iron formation. (2), Progressive stages in the removal of siliceous material, with some specimens showing only a few of the siliceous pebbles partly dissolved out, others showing considerable solution and finally, in some specimens, practically all of the siliceous fragments completely removed leaving a porous rock that was still quite heavy from the iron oxide in the matrix and remaining pebbles. (3), Specimens showing solution cavities with various amounts of iron oxide in them, ranging from those specimens with only a thin coating of small magnetite crystals lining the cavities to specimens where the former cavities are completely filled with magnetite (or hematite altered from magnetite).

Kiril Spiroff has shown that magnetite can be formed under conditions of low temperature and pressure. In an article in Economic Geology, Vol. XXXIII, No. 8, December 1938, Spiroff states that "primary magnetite crystals occur in vugs and as a filling in leached iron ore conglomerate on the Mesabi Range, Minnesota. From the field observations and from magnetite crystals developed in the laboratory, the conclusion is drawn that magnetite can be formed as a precipitate from meteoric waters".

No attempt was made to determine which of the above processes was responsible for the ore in any given part of the area, nor at what time the ore may have been formed. It was clear, however, that at least some small amount of ore may have been formed by Goodrich time and also that a large portion of some deposits has been formed since the last main folding and faulting in the area as the position and trend of many of the ore bodies were apparently determined by structures induced by deformation of the iron formation during the Superior revolution.

In both the Negaunee and the Bijiki horizons the ore occurs where circulation of underground waters or solutions up or down the dip or along the strike have been guided or impeded by rolls or folds in the formation, or by dikes or faults that cut it.

It now appears that ore has been formed from practically all phases of the iron formations including even the grüneritic phases that have usually been considered too resistant to ore forming processes. Considerable of the ore formed, presumably since the time of the Superior revolution, has been formed from grüneritic rocks in the Bijiki iron formation west of Michigamme, and probably in other localities.

In the Lake Michigamme area, as in the Marquette Range in general, ore occurs in the following horizons. (1), The Negaunee iron formation, especially, but not necessarily, at or near the top. (2), The base of the Goodrich conglomerate where it rests directly upon the Negaunee iron formation. (3), The Bijiki iron formation.

Of these three horizons it can be expected that the largest tonnage of ore will probably come from the thicker Negaunee iron formation when that formation is sufficiently explored and developed. In the past, most of the development work in this area has been done in the Bijiki horizon.

To date the only large producers in the Negaunee horizon have been the Champion Mine at Beacon, the Michigamme Mine at Michigamme and the Spurr Mine just west of there.

Each of the above mines have produced some ore from the horizon at the base of the Goodrich.

Among the mines that have produced ore from the Bijiki horizon are, from east to west, the Hortense, Pasco or North Phoenix, Dalliba or Phoenix, and the Marine, all east of the Peshekee River. No producing mines were opened on this horizon in Township 48 North, Range 30 West. Westward from Michigamme the mines in the Bijiki horizon included the Imperial, Webster, East Portland, Ohio, Norwood, Beaufort and the Titan.

RECOMMENDATIONS for EXPLORATION

The following portions of the Lake Michigamme area are considered the more favorable for exploration. They are underlain by either the Negaunee or the Bijiki iron formations, or by both. No recommendations are being made separately for the Goodrich, as that horizon is not likely to be productive unless the underlying Negaunee iron formation also contains ore.

These recommendations are based upon the indications of structure obtained from the comparatively few outcrops in the areas mentioned, the interpretation of the topography and the evidence obtained from the magnetic survey. Outcrops of the iron formations are scarce or entirely lacking in much of the area under discussion, and drilling records are either non-existent or were not available, so the following account should not be considered as a definite statement of the structure and potential value of any particular part of the area. It is hoped, though, that the recommendations, together with the information shown on the accompanying maps, may be of some service as a guide to future explorations.

The results from one drill hole, as will be frequently indicated in the text, may have a great effect upon the recommendations given for adjacent parts of the area.

T. 47 N., R. 29 W.

Section 4.

```
+   +   +   +   +
  3   3   3   3
+   +   +   +   +
  3   3   2   2
+   +   +   +   +
  2   2   1   1
+   +   +   +   +
  0   0   0   2
+   +   +   +   +
```

The topography and the dip needle readings, taken in conjunction with the indications from outcrops in the western part of this section, suggest that there may be a mile long, crumpled trough of iron formation, striking east and west through part of sections 3 and 4 just south of the east 1/4 post of Section 4. This area is underlain by the Bijiki iron formation and at greater depth by the Negaunee. Both of these formations are probably within mining depth. Both are probably mostly grüneritic except near the top.

Any vertical, or steeply south dipping, drill hole in the center of the NW¼ of the SE¼, and another similar hole about 600 yards due east of there, near the east line of the NE¼ of the SE¼, should show the character of, and depth to the formations. These holes should furnish sufficient evidence to determine whether a north and south line of holes across the NW¼ SE¼ and into the south half of the NE¼ would be advisable, and also whether exploration should be continued into the north half of the SW¼ or the SE¼ of the SE¼ of the section, all of which forties are underlain by one or both iron formations.

Any exploration in the NW¼ of the section should be deferred until information from the above drilling is obtained. The west half of the NW¼ has numerous outcrops of Bijiki and Clarksburg and the structure is quite complicated by close folding, faulting and the probable presence of intrusives, hence early exploration is not recommended for this part of the section.

Most of the S½ of the SW¼ and part of the SW¼ of the SE¼ are not underlain by any iron formation and can not be expected to contain ore.

The diagram above shows (1) the most promising forties, (2) the forties that should be explored if the first areas show ore, (3) the least favorable forties underlain by iron formation, and (0) those forties that do not carry enough of the iron formations to warrant exploration at present.

Section 5.

Very little of this section, except the northeastern part, is underlain by any iron formation, and in most of this portion the structure is so complicated by folding, faulting and intrusives that exploration may not be advisable at present although there may be some ore found close to the great fault that roughly parallels the C. M. St. P. & P. tracks through part of the E½ of the NE¼. Ore may lie against, or close to this fault in the swamp on the east side of it and just west of the east 1/4 post of the section, or on either side of the fault near the west edge of the NE¼ of the NE¼.

Section 6.

No part of this section is underlain by the iron formation.

T. 47 N., R. 31 W.

Section 10.

A fairly strong, persistent and straight magnetic belt, probably due to northward dipping Bijiki iron formation, runs westward from just north of the east 1/4 post of the section.

Drill holes, located about 700 feet west and 250 feet north, and about 1400 feet west and 100 feet north of the east 1/4 post, and inclined about 60° to the southward would show the character of this formation which is close to surface here but does not outcrop in this nor adjacent sections.

Section 11.

The same magnetic belt that was mapped in Section 10, crosses section 11, without outcropping, from near the west 1/4 post to a point about 1300 feet south of the northeast corner. If drilling is done, it should probably be close to the belt and on the north side of it with the holes inclined southward.

Section 12.

The same belt that was followed across sections 10 and

11, extends diagonally from about 1300 feet south of the northwest corner of Section 12 to near the southeast corner. Near the center of the southeastern quarter of the section are a few low outcrops of grüneritic material dipping northeastward. The material, both from the ledge and some shallow pits in the vicinity, is a limonitic alteration quite similar to much of the material seen at the Webster and other old mines in the Bijiki horizon westward from Michigamme.

The pits appear to be too far in the foot for satisfactory results. It would seem that a better place for exploration would be about 2,000 feet to the northwestward, with drill holes put down well to the northeastward of the belt and inclined to the southwestward.

T. 48 N., R. 29 W.

Section 19.

A strong magnetic belt that is probably due to southward dipping Negaunee iron formation, extends a short distance eastward from a point about 700 feet north of the southwest corner. The iron formation does not outcrop within several miles of here, but the magnetics are so located relative to the exposed base of the Ajibik to the northward, and the Bijiki to the southeast, that there can be little doubt but that this belt is due to the Negaunee iron formation. The iron formation may continue eastward across the southern tier of forties in this section but the magnetics are weak and no explorations are recommended here until drilling is done on the adjacent section (Section 30) to the south.

Section 28.

A magnetic belt, probably due to south dipping Negaunee iron formation, was crossed about 500 paces south of the northeast corner. What is probably the same belt was found a few paces south of the northwest corner and followed for a short distance, but not far enough to determine whether or not it continued across the section. In each case the belt was about 200 paces in width and moderately strong, giving a dip needle rise of from 6° to 12° (adjusted values). No outcrops exist along this stretch of swamp and low blueberry plains. On each side of the section, the magnetic belt was about 150 paces south of the cliffs of northeasterly striking granitized Kitchi sediments.

Drilling along this stretch is not recommended until more geological mapping has been done as in the bluffs to the northwest there is faulting of such character that portions of the iron formation may be locally cut out, with the result that the drill holes might go from the Goodrich into the old granitic rocks without intersecting any of the Negaunee iron formation. There is no indication, however, that the Negaunee was removed by erosion before Goodrich time.

A strong but narrow magnetic belt was followed from a point about 200 paces north of the west 1/4 post toward the center of the section. Somewhere east of where the mapping was discontinued this belt is either folded or faulted out of position as it was not picked up in the line of strike in a northeast line that was run across the SE$\frac{1}{4}$ of the section. This belt may be due to southward dipping Bijiki, possibly a tight fold with both limbs dipping southerly. The magnetic belt is continuous westward through the Hortense Mine in the next section. There are several shallow test pits on this magnetic belt in this section, many of them showing only graphitic slate.

Future explorations in this section may find ore but no recommendations can be made at this time as the geological mapping is not yet complete.

Section 29.

3	3	3	3
1	1	P 2	H 2
2	4 D	4	2
0	0	0	0

D = Dalliba (or Phoenix Mine)

P = Pascoe (or North Phoenix)

H = Hortense Mine

0 = Either not underlain by iron formation or the iron formation is too deep.

1 = The most promising areas

2 = Apparently poorer areas for exploration.

3 = Underlain, at least in part, by iron formation, but geological mapping not completed.

4 = Probably underlain by iron formation but not much chance for ore.

Above is a diagram of Section 29 and a list of the symbols used.

No mapping was done north of the Chicago and Northwestern Railroad except near the east line of the section where the south dipping Negaunee iron formation was located magnetically. The faulting problems, mentioned in the discussion of Section 28 to the east, applies still more emphatically to this section, and should be worked out by careful geological mapping before drilling in the north tier of forties can be recommended.

From the Pascoe (or North Phoenix) pit in the SW¼ of the NE¼, a strong magnetic belt was followed westward to just across the west line of the section, where it was found to bend back sharply to the eastward to a point about 700 paces east and 450 south of the northwest corner. Here it either stops abruptly in a zone of low readings, or else bends rather suddenly to the southeastward and continues, with greatly reduced magnetism, to the north side of the Pascoe pit. Where the fold in this belt is the widest, about 500 or 600 paces east of the west line, the two belts are about 600 feet apart. From the dip needle readings this appears to be an eastward pitching syncline with both limbs dipping southward. If such is the case then there may be ore in this trough, going deeper to the eastward. A drill hole, located about the center of the SW¼ of the NW¼, inclined 50° to 60° to the northward should cut the formations of each belt (both sides of the fold) within about 1,000 feet from surface. If there are favorable indications at this place, then the deeper part of the trough to the eastward could be explored and also the sharp fold or cross fault just west of the Pascoe.

Between the Pascoe (SW¼ of the NE¼) and the Hortense (SE¼ of the NE¼) there is seemingly some chance for additional, low grade ore. The dip needle readings indicate that iron formation underlies much of the southern half of the Hortense forty and the north part of the forty immediately to the south, but it is likely that the ore may lie rather deep or be of low grade.

In the forty immediately east of the Dalliba (or Phoenix), which is in the NE¼ of the SE¼, there seems little likelihood of any considerable amount of ore, but in the forty just west of the Dalliba there might be an appreciable amount of fair grade ore, especially at depth.

In most of this section south of the C. & N. W. R.R., the magnetic belts are due to the Bijiki but the Negaunee iron formation also underlies much of the area but probably at depths generally greater than 2,000 feet. There should be some ore in the Negaunee horizon but it will probably be difficult to locate. While there is only a minor unconformity between the Bijiki and the Negaunee, the upper formations are quite apt to be much more intricately folded than the lower, and so a moderately broad trough of the Negaunee might underlie several smaller folds of the Bijiki, and the center of a Negaunee trough might conceivably be directly under one of the anticlines of Bijiki.

The rest of this section is not very promising as there are east and west striking anticlines of Goodrich, such as the one exposed just south of the Dalliba (Phoenix).

Section 30. (48-29)

4	4	4	0
4	4	0	0
3	0	2	2
		M	
2	1	0	0

0 = Either not underlain by iron formation or formation not favorable for ore.

1 = Area most likely to contain ore.

2 = Area where geological conditions warrant exploration.

3 = Exploration not recommended at present.

4 = Poor chance for ore, or ore bodies too deep or too difficult to locate at present.

M = Marine Mine.

The northwest quarter of this section, judging from the dip needle readings, appears to be underlain by iron formation although no outcrops were found. Several strong to moderately strong magnetic belts were mapped but none of them were traceable for more than a few hundred feet and are probably due to small tight folds in the Bijiki. Exploration of this part of the section should perhaps best wait upon results of drilling in the forties immediately to the west (in Section 25, T. 48 N., R. 30 W.), where the geological conditions appear to be more favorable for the occurrence of ore bodies.

Most of the northeast quarter of the section was not mapped in detail as the only definite magnetic belt found striking into it is the one that runs just across the east line, from the direction of the Pascoe Mine in section 29; and almost immediately is bent back out of the section.

From the Marine Mine, near the center of the SE$\frac{1}{4}$ of the section, a trough of Bijiki extends a little north of east to the Dalliba in Section 29 so it is probable that a little lean ore may be found in the southern part of the NE$\frac{1}{4}$ of the SE$\frac{1}{4}$.

Southeast of the Marine, the southern limb of this trough swings to the southward past the south 1/4 post and is anticlinal in general structure with probably only small synclines with only a little lean ore likely to occur in them.

The SE$\frac{1}{4}$ of the SE$\frac{1}{4}$ appears to be mostly Goodrich that is probably considerably folded, faulted and generally anticlinal in structure. What appears to be Michigamme schist was found, apparently in place, near Goodrich graywacke with no indication of the Bijiki between. Lack of outcrops or magnetic belts rendered it difficult to determine whether the relations were due to faulting or to a volcanic vent in this area.

There is a small, water filled pit, about 700 feet northwest of the Marine, that appears to be on the north limb of the same trough, although there are some indications that there may be a minor anticline between. This north limb, dipping steeply southward, was followed practically continuously for about a mile and a half westward to the mouth of the Peshekee River, and it seems likely that there may be some ore just south of this belt in the northern part of the S½ of the SW¼. No evidence of explorations along this belt were seen between a small, water filled pit, about 150 paces west and 520 north of the south 1/4 post, and Lake Michigamme.

Most of the NE¼ of the SW¼ of this section is underlain by anticlinal Goodrich, but in the NW¼ of the SW¼ there are a couple of narrow troughs, outlined by high magnetic readings, in which no evidence of exploratory work was found except for a line of shallow test pits crossing the formation near the west line of the section.

Section 31.

```
+    +    +    +    +
  0    4    0    0
+    +    +    +    +
  0    0    0    4
+    +    +    +    +
  4    4    4    4
            Beacon
+    +   C+    +    +
  1• • °2    3    3
+    +    +    +    +
```

Section 31 (T. 48 N., R. 30 W.)

C = Champion cave-in.

•°° = Champion mine shafts

1 = most promising area

2 = probable ore at depth, should be further explored.

3 = mostly worked out near surface, but probably some more ore.

4 = ore probably too deep, or low grade.

0 = little or no chance for ore.

The northwest quarter of this section is probably underlain by Michigamme formation and Clarksburg volcanics, with the iron formations, where present, mostly too deep to be of much value.

The northeast quarter contains Bijiki iron formation in a badly crumpled, interrupted and steeply south dipping belt. The Bijiki horizon is not apt to contain any large or readily accessible ore bodies and the Negaunee formation is probably deeply buried.

The southeast quarter shows outcrops of grüneritic Negaunee iron formation with a relatively thin zone of magnetite, specular hematite and granular quartz at the top. This is overlain by Goodrich, Bijiki and a great deal of Clarksburg. The dips are quite steep to the northward. In this part of the section, the Negaunee and Goodrich horizons have been pretty well explored and mined except at depth, where there is a good chance for more ore.

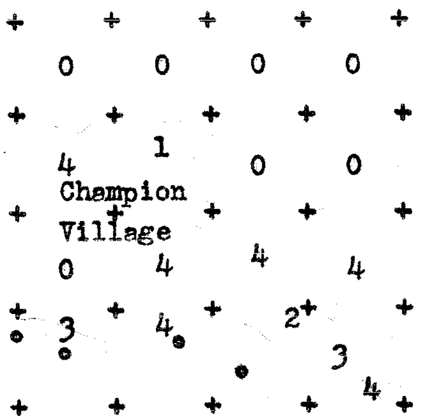
The NW$\frac{1}{4}$ of the SW$\frac{1}{4}$ is underlain by the Negaunee and Bijiki iron formations, both of which are probably mostly on the nose of a northeasterly plunging anticline.

The NE$\frac{1}{4}$ of the SW$\frac{1}{4}$ is probably underlain by a deep trough of the iron formations pitching to the northeastward. This is apt to contain much ore at considerable, but probably not prohibitive, depth, in both the Negaunee and the Goodrich horizons.

The SE$\frac{1}{4}$ of the SW$\frac{1}{4}$ contains the main workings of the Champion Mine and is presumably pretty well worked out except in depth where a considerable tonnage of ore should still be found in both the Negaunee and the Goodrich formations.

The SW$\frac{1}{4}$ of the SW$\frac{1}{4}$ appears to carry a northeastward pitching trough of iron formations that is likely to carry ore, especially in the Negaunee horizon, at moderate to considerable depth.

Section 32 (T. 48 N., R. 29 W.)



1 = Good chance for ore.

2 = Likely to be ore at considerable depth.

3 = Probably small ore bodies, mostly at depth.

4 = Possibly ore at depth.

0 = Little or no chance for ore.

°°° = Small open pits.

The entire northeast quarter of this section is devoid of any definite magnetic belts and contains several outcrops of Goodrich quartzite. The Negaunee iron formation probably underlies much of this quarter section but too deeply to warrant exploration at present as its structure has not been determined.

The north half of the NW$\frac{1}{4}$ is also underlain by Goodrich and perhaps in places by volcanics and any iron formation that may be present is probably too deep for exploration. Exploration should be postponed until more is known about the structure.

The SW$\frac{1}{4}$ of the NW$\frac{1}{4}$ is mostly low and swampy with a contorted, broken belt of steeply south dipping Bijiki iron formation skirting the northern edge. Ore might underlie part of this swamp but the indications are that it would be very deep and the grade and tonnage rather low. It is also probable that a considerable thickness of Clarksburg or Michigamme would be encountered in any drilling here.

In the SE$\frac{1}{4}$ of the NW$\frac{1}{4}$ there is strong evidence of a trough of grüneritic Bijiki iron formation pitching steeply to the southwest. This trough is likely to contain some ore of satisfactory grade. If drilling is done on this forty it would probably be best to locate the first vertical hole about 1800 or 1900 feet east and 950 to 1,000 feet north of the west 1/4 post. Another hole might be drilled near the forks in the road, about 1650 feet east and 550 feet north of the west 1/4 post, so that this hole would go down south of what may be a minor anticline in the trough.

The NW$\frac{1}{4}$ of the SW$\frac{1}{4}$ is underlain by Clarksburg and Michigamme formations with what is probably a faulted anticline of Bijiki striking east and west near the north edge of the forty. There seems to be no reasonable chance for ore and as the main street of Champion Village runs through this forty no exploration is recommended.

The NW$\frac{1}{4}$ of the SW$\frac{1}{4}$ includes much of the town of Champion, the railroad yards and highways. The only likely looking place for ore is in the northeast corner of this forty where a vertical drill hole, located a few feet southwest of the center of the section, might encounter a moderate amount of rather lean ore in what appears to be a westward pitching syncline in grüneritic Bijiki iron formation.

The SW$\frac{1}{4}$ of the SW$\frac{1}{4}$ carries a belt of grüneritic Negaunee iron formation, similar to that already described in Section 31 to the west. The dips are steep to the north and the Negaunee is directly overlain by the Goodrich iron bearing horizon and the Bijiki. This area seems to have been quite thoroughly explored and considerable mining was done near the surface. Additional ore may be expected in depth, especially where the formation locally flattens down the dip or where it is cut by dikes.

The SE$\frac{1}{4}$ of the SW$\frac{1}{4}$ carries the continuation of the belt of grüneritic Negaunee iron formation that occurs on the forty to the west, but here the formation has begun to curve to the southeast, is mainly anticlinal with only minor troughs and offers little chance for much ore. There are numerous shallow pits in this forty and a little mining was done along the Goodrich contact.

In the SW$\frac{1}{4}$ of the SE$\frac{1}{4}$, the Negaunee iron formation strikes about southeast and the chance for any important tonnage of ore in either the Negaunee or Goodrich horizons seems rather remote except in what may be an eastward pitching trough near the middle of the east line of this forty. This probable trough may exist between the northeast dipping Negaunee and Bijiki iron formations and what is probably a minor anticline near the northeast corner of the forty, where there is a fairly strong magnetic belt. This belt is apparently due to the Bijiki coming close enough to the surface beneath the Clarksburg to give a fairly strong magnetic belt extending for several hundred feet in an east-southeast direction toward and across into the adjoining forty to the east. The only outcrops found along this narrow belt were of Clarksburg graywacke, apparently near its base.

The SE$\frac{1}{4}$ of the SE$\frac{1}{4}$. The probable trough, discussed in the description of the forty to the west, pitches down into the northwestern part of this forty and may end against a north and south fault that presumably lies under the swamp along the C.M. St. P. & P. railroad. A vertical drill hole put down about 600 feet north and 1250 to 1300 feet west of the southeast corner might encounter ore in the Negaunee horizon after going through the Bijiki and the base of the Goodrich, either of which may also carry some ore. If ore is found in the Negaunee formation it is apt to be over 2,000 feet down, but it would probably continue down the trough to the north and south fault mentioned.

In the southeastern part of this same forty there are abundant outcrops of Bijiki and the immediately overlying Clarksburg tuff. The Bijiki is partly grüneritic and partly unoxidized iron carbonate at the top. It occurs in a series of crumpled and faulted folds, most of which are striking southeasterly, but some of them are twisted around at about right angles to the general trend.

In the N½ of the SE¼ there may be a considerable tonnage of ore deep under the swamp north of the D. S. S. & A. railroad, but this would probably be low grade ore in the Bijiki horizon, as the Negaunee is likely to lie at an almost prohibitive depth along here.

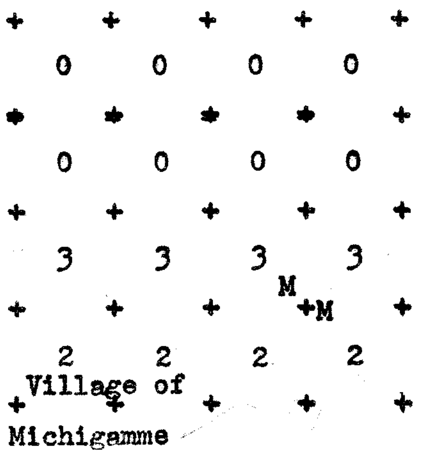
There is a westward pitching syncline of considerably drumpled grüneritic Bijiki lying along the north line of the NW¼ of the SE¼ but it is not likely to carry much ore except near the center of the section.

Section 33.

No detailed mapping was done in this section but a few careful traverses were run in the southern tier of forties and in the north half of the NW¼. No magnetic belts were crossed on any of these traverses. Time did not permit the running of this section, nor of any of the other sections in this township east of the east line of Sections 21, 28, and 33.

T. 48 N., R. 30 W.

Section 19.



2 = Probably ore at depth

3 = Small ore bodies near surface, with probably more ore in depth.

0 = Not underlain by iron formations.

MM = Michigamme Mine.

No part of the north half of this section is underlain by iron formations, other than a thin, non-productive zone at the base of the Negaunee.

The N$\frac{1}{2}$ of the SW$\frac{1}{4}$ and the N$\frac{1}{2}$ of the SE$\frac{1}{4}$ are crossed by several nearly parallel belts of Negaunee iron formation separated by Clarksburg dikes or sills of coarse uralitic gabbro. These four forties also carry the Goodrich and Bijiki horizons. The only mining operations in this section were carried on at the Michigamme Mine, in the N$\frac{1}{2}$ of the SE$\frac{1}{4}$, and were almost entirely confined to the top of the Negaunee and the base of the Goodrich.

The iron formations dip steeply southward, are highly grünеritic and are separated by less than 100 feet of the intervening Goodrich which is mostly dark quartzite. All of the exposed Negaunee iron formation is of the grünerite-magnetite phase except for a relatively thin zone directly below the Goodrich. This upper part of the formation consists of magnetite banded with medium coarse to very fine granular quartz. It was not determined whether or not any similar belts of the iron formation exist immediately below any of the Clarksburg intrusives as no exposures were found close on the north side of the intrusives.

Along the south tier of forties in this section there is probably a long trough of iron formation, as about 2,000 feet to the south of the Goodrich contact there is an anticline or upthrust of Bijiki with indications of another one about half way between. This trough, or the north one in particular if there are two, will be rather narrow but probably quite deep and may have both limbs dipping southward. It is apt to contain ore in the Negaunee horizon deep under part of the town of Michigamme. If a large ore body does exist here it might be possible to reach it, either by following down the Goodrich contact to it, or by deep drilling in the low ground south of the D.S.S. & A. tracks. This trough may also contain some lean ore in the Bijiki horizon and a little ore in the bottom of the Goodrich.

Section 20.

```
+    +    +    +    +
  0    0    0    0
+    +    +    +    +
  0    0    0    0
+    +    +    +    +
  4    4    0    0
+    +    +    +    +
  3    0    0    0
+    +    +    +    +
```

3 = Small ore bodies near surface, with probably more ore in depth.

4 = Possible ore at depth.

0 = Either no underlying iron formations (in the northern half)
or
0 = Underlain, at least in part, by iron formation but beneath Lake Michigamme.

There are no iron formations underlying the north half of this section. The $N\frac{1}{2}$ of the $SW\frac{1}{4}$ carries the same belts of Negaunee iron formation, separated by Clarksburg dikes or sills, as occur in Section 19 immediately to the west. These forties lie entirely north of the Goodrich contact, and seem to offer but little promise of much ore.

The $SW\frac{1}{4}$ of the $SW\frac{1}{4}$ carries the top of the Negaunee, the Goodrich and probably part of the Bijiki close to the shore of Lake Michigamme, but these formations are under Lake Michigamme except close to the west line of the section.

The rest of the section either carries only the lower part of the Negaunee iron formation or is under the lake.

Section 21.

0	0	0	0
0	0	0	0
4	4	4	4
4	4	4	3

3 = Underlain by Negaunee, Goodrich and Bijiki. Has some possibilities of ore.

4 = Underlain only by lower part of the Negaunee and by Clarksburg
or else
Is mostly under Lake Michigamme.

0 = Not underlain by iron formation.

There are no iron formations in the northern half of this section.

The $N\frac{1}{2}$ of the $SW\frac{1}{4}$ and the $NW\frac{1}{4}$ of the $SE\frac{1}{4}$ are underlain by the lower part of the Negaunee iron formation and by Clarksburg intrusives. There are no outcrops of iron formation or Goodrich, but from the magnetic survey, the structure is probably similar to that in the $NW\frac{1}{4}$ of the $SW\frac{1}{4}$ of Section 20, and these forties are not likely to carry any appreciable amount of ore.

The $NW\frac{1}{4}$ of the $SE\frac{1}{4}$ has a little of the bottom part of the Negaunee cutting somewhat diagonally across the extreme southwestern part. Probably no ore.

The $SE\frac{1}{4}$ of the $SE\frac{1}{4}$ is underlain by the top of the Negaunee, there being a very strong magnetic belt occurring in the northern part of this forty, crossing the road to Presbytery Point near its junction with the road to Brown's Beach. Just south of this strong belt, the Goodrich and the Bijiki were located only by the dip needle survey. All formations appear to be dipping southward.

There may be ore on this forty and perhaps also on the forties to the west as a long bay of Lake Michigamme that runs east from the mouth of Ketchewa Bay may indicate a synclinal structure or a fault, although the dip needle gave no positive indications of such a structure favorable for ore.

Section 22.

+		+		+		+		+
	0		0		0		0	
+		+		+		+		+
	0		0		0		0	
+		+		+		+		+
	4		4		4		0	
+		+		+		+		+
	3		3		3		3	
+		+		+		+		+

3 = Possible trough and ore.

4 = Lower part of Negaunee iron formation and Clarksburg intrusives with not much chance for ore.

0 = No underlying iron formations.

No iron formation occurs in the north half of this section.

The N$\frac{1}{2}$ of the SW$\frac{1}{4}$ and the N$\frac{1}{2}$ of the SE$\frac{1}{4}$ are underlain by bands of the lower part of the Negaunee iron formation between which lie one or more Clarksburg sills or dikes. The only outcrops found south of the bluffs of granitized Kitchi were the Ajibik quartzite, near the north edge of this tier of forties, and knobs or ridges of Clarksburg coarse uralitic gabbro, all striking about east and west.

In the southern tier of forties there is a fairly strong magnetic belt, near the D. S. S. & A. R.R., probably due to underlying Negaunee iron formation. Another belt of quite high readings runs close to the south line of the section. The zone of somewhat lower readings between these two magnetic belts may represent the Goodrich, a Clarksburg intrusive, a syncline or a fault zone. Because of a long swamp across the south part of this section, just south of the railroad, it seems more likely that there may be a trough close to the south line, in which case there may be a good chance for ore in these forties.

Section 23.

0	0	0	0
0	0	0	0
0	0	0	0
3	3	3	4 B

3 = Possible ore under Clarksburg gabbro.

4 = Partly underlain by the lower part of the Negaunee iron formation, but no probable ore.

0 = No iron formations present.

B = Location of dip check "B" at base camp.

There are no iron formations in the N$\frac{1}{2}$ of the SW$\frac{1}{4}$, the N$\frac{1}{2}$ of the SE$\frac{1}{4}$ nor the entire north half of this section.

At least the lower part of the Negaunee iron formation underlies a portion of each forty in the southern tier of forties. A uralitic gabbro ridge of Clarksburg strikes about N 85° W across the southern part of the SE$\frac{1}{4}$ of the SW$\frac{1}{4}$ and the SW$\frac{1}{4}$ of the SE$\frac{1}{4}$. The south 1/4 post of the section is on the south edge of this ridge. Footwall slates of the iron series outcrop along the northern flank of the ridge and fairly strong magnetic belt occurs near the edge of the long swamp on the south side of the same ridge.

A few dip needle traverses were run northward from the magnetic belt to well beyond the north edge of the ridge and the rather high readings obtained indicate that iron formation underlies both the gabbro and the footwall slate, and that a thrust fault probably occurs along the north edge of the ridge. An apparent break in the iron formations about 3/4 of a mile to the eastward lines up with this probable fault. With such a fault in this position there may be ore in a narrow trough just north of, and perhaps partly below, the gabbro. Ore is even more probable on the south side of the gabbro ridge but mostly in Section 26 immediately to the south, and this possibility will be discussed where that section is described.

Section 24.

```
+    +    +    +    +
  0    0    0    0
+    +    +    +    +
  0    0    0    0
+    +    +    +    +
0 0    0    0    0
+    +    +    +    +
  0    0    3    4
+    +    +    +    +
```

3 = Underlain by Negaunee iron formation with chance for ore.

4 = Underlain by Negaunee iron formation with little chance for ore.

0 = No iron formations present.

There are bluffs of gneissoid Kitchi on all forties in this section, in some places the granitized sediments coming to within 350 paces of the south line.

A strong magnetic belt, presumably due to south dipping Negaunee iron formation, crosses the east line of the section about 200 paces north of the southeast corner, and from 200 to 250 paces south of the bluffs of Kitchi graywacke. This belt runs westward across the S$\frac{1}{2}$ of the SE$\frac{1}{4}$ to within 200 paces of a bayou of the Peshekee River, where it curves southward toward the south 1/4 post with the dip needle readings decreasing rapidly as the belt nears the quarterpost. The magnetic survey does not show whether this decrease in magnetism of the belt is because it is (1), faulted off in the vicinity of the river, (2) fades out because of increase in the depth of overburden, (3) has a flatter dip, (4) was less highly metamorphosed, (5) has been more weathered here than usual, or (6) has become less strongly magnetic for some other reason.

Whichever of the above conditions that have prevailed it seems that exploration in this forty might be warranted as there appears to be a reasonably good chance for ore in the vicinity of this bend in the magnetic belt. A drill hole might best be located about 600 feet east and 100 feet north of the quarterpost, the hole inclined steeply northwest.

Section 25. (T. 48 N., R. 30 W.)

B

4	4	2	3
3	4	4	4
0	4	4	3
0	0	0	0

2 = Probably some ore.

3 = May carry ore, but ore probably low grade or else quite deep.

4 = Underlain by iron formations but not likely to carry much ore except at a considerable depth.

0 = Underlain by iron formation but at considerable depth or else under the lake.

B = Base Camp.

Except for Clarksburg intrusives, this entire section is underlain by the Negaunee iron formation, and all but the N½ of the NW¼ probably also carries both the Goodrich and the Bijiki horizons.

A fairly strong, well defined magnetic belt enters the NW¼ of the NW¼ from the west, but near the middle of the forty this belt rapidly broadens into a zone about 300 paces wide with the dip needle readings less than 4° higher than in the adjacent area on either side. In the south central part of the NE¼ of the NW¼ the belt weakens still more and then disappears into the Peshekee River where it was not followed. The belt emerges on the east side of the river a little east of and about 500 paces south of the north 1/4 post. From this place it gradually becomes stronger and swings northeastward until it again becomes a well defined, fairly strong belt where it is striking northeasterly about the middle of the NW¼ of the NE$\frac{1}{4}$, from where it hooks rather sharply to the northward and is lost in a zone of low readings.

What is probably the same belt, offset 300 or more paces to the westward, starts near the north 1/4 post, runs northeasterly toward the middle of the SW$\frac{1}{4}$ of the SE$\frac{1}{4}$ of Section 24 immediately to the north, and then turns eastward.

The Clarksburg gabbro that outcrops near the north 1/4 post of Section 26, immediately to the west, strikes directly into the zone of lower dip needle readings that separate the two portions of this belt. It would seem that in the extreme northern pårt of this forty there is likely to be a southeastward pitching syncline, cut off or modified by an east and west thrust fault. This structure should favor the presence of an ore body. There is apt to be basic dike material in and near the thrust fault.

The NE$\frac{1}{4}$ of the NE$\frac{1}{4}$ may carry a continuation of any ore body located in the forty must described.

The S$\frac{1}{2}$ of the NE$\frac{1}{4}$ is underlain by both iron formations and is probably a crumpled syncline with small troughs, some pitching westward and some to the north of eastward. Both formations are probably quite deep. These two forties are included in Van Riper Park.

The SW$\frac{1}{4}$ of the NW$\frac{1}{4}$ is underlain by the Negaunee and also probably by the Bijiki and the Goodrich. There may be ore in this forty although the magnetic survey gave no indication of any particularly favorable structure. About half of this forty lies in Lake Michigamme.

The SE$\frac{1}{4}$ of the NW$\frac{1}{4}$ is underlain by iron formations at considerable depth. The structure is probably anticlinal with small, deep lying irregular troughs pitching mostly to the westward. The conditions do not appear especially favorable for ore. This forty is also included in the Van Riper Park area.

The $NE\frac{1}{4}$ of the $SW\frac{1}{4}$ contains outcrops of anticlinal grüneritic Bijiki striking and pitching about S 70° W. The only likely place for ore would be deep under the mouth of the Peshekee River and the ore would probably be low grade.

The rest of the $SW\frac{1}{4}$ of this section is entirely in Lake Michigamme.

The $N\frac{1}{2}$ of the $SE\frac{1}{4}$ contains numerous outcrops of grüneritic Bijiki and a little of the footwall graphitic slate in a series of small sharp badly crumpled folds. There seems to be little chance for ore within 2,000 feet of surface except for relatively small amounts of low grade material just southwest of the east 1/4 post. As these two forties are also underlain by the Negaunee iron formation, there is of course a chance for some ore in the Goodrich and Negaunee horizons at depth, but it would probably be difficult to locate it until deep exploration work is carried out in some of the nearby areas that seem to be more favorable. These forties are also a part of Van Riper Park.

The $S\frac{1}{2}$ of the $SE\frac{1}{4}$ is practically all under Lake Michigamme.

Section 26. (T.48 N., R. 30 W.)

3	2	2	B 3
3	3	3	4
0	0	0	0
0	0	0	0

4 = Underlain by iron formation but ore (if any) probably deep or under the lake.

3 = Probable ore. May be lean, or else at considerable depth.

2 = Probably ore.

0 = Underlain by iron formations but under Lake Michigamme.

B - Base camp.

The geological mapping of this section was not completed despite the fact that the base camp was located on it near the northeast corner. The entire section was so handy to the camp that most of the mapping was deferred until such time as poor weather or other circumstances might render field work farther from camp impractical. Hence this conveniently located area was held in reserve so long that it has not yet been properly mapped. Most of the mapping that was started in this section was done by assistants during the early part of their training while their mapping and dip needle work had not yet been proved reliable.

Such work as has been done shows that a very strong magnetic belt, striking between S 80° and 85° east, occurs about 100 paces north of the northwest corner and enters this section about 400 paces west of the north 1/4 post, crosses the center line about 50 paces south of the north 1/4 post and passes out of the section about 300 paces south of the northeast corner, with the dip needle readings steadily diminishing for the last 200 paces in the eastern part of the section. For about one-quarter of a mile on each side of the north and south center line this belt is about parallel to a prominent Clarksburg ridge of uralitic gabbro which stands up as a nearly vertical cliff from 50 to 100 paces north of the magnetic belt.

Several other magnetic belts, most of them quite strong, occur between this northern belt and the lake shore. These belts strike from about N 80° W to N 80° E and are in two main groups that seem to represent two crumpled anticlines between the gabbro ridge and the lake shore. Numerous outcrops of grüneritic material were found along these belts, especially the southern group which, dipping southward, forms a good deal of the north shore line of Lake Michigamme.

It seems that there are two main sylcines of Bijiki, one north of each Bijiki anticline, running east and west across this section. In either of these there may be ore in the Bijiki horizon. The northern trough is also likely to contain ore in the Goodrich and Negaunee horizons that will probably be within mining depth of the surface. This could probably be determined by a series of north and south drill holes across the swamp, south of the railroad, on either side of the small lake that lies just south of the north 1/4 post.

Section 27. (T. 48 N., R. 30 W.)