Geology of the Lake Michigamme area, Baraga and Marquette Cos.

by W. A. Seaman

(Open File Report)

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STATE OF MICHIGAN

DEPARTMENT OF CONSERVATION

GEOLOGICAL SURVEY DIVISION

GEOLOGY

of the

LAKE MICHIGAMME AREA

Baraga and Marquette Counties

By W. A. Seaman

Prepared in cooperation with
The Michigan College of Mining & Technology

1947

FOREWORD

This publication is the result of four years field work by Professor W.A. Seaman of the Michigan College of Mining and Technology, under a cooperative program between the Michigan Geological Survey and the Michigan College of Mining and Technology.

At the present time publication of this report for distribution is not possible due to the excessive cost of printing the voluminous report and reproducing the great number of maps which would require color for interpretation. The report has, therefore, been placed on open file in line with the Michigan Geological Survey's policy of making geological information available to interested parties as quickly as possible.

The views stated in this report are those of the author and are not necessarily shared by the Michigan Geological Survey of the Michigan College of Mining and Technology.

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GEOLOGY OF THE LAKE MICHIGAMME AREA

The area mapped in detail and shown on the index map, Plate I, is twelve miles long from east to west with a maximum width of about five miles and takes in most of Lake Michigamme and the villages of Michigamme and Champion.

Eastward from Lake Michigamme the detailed mapping included not only the iron bearing series but also much of the foot-wall formations on each side of the trough. West of the Peshekee River the foot-wall formations were found only on the north side.

Most of the work in the area was done in 1946 and 1947, although some previous work, from 1943 to 1945, is included. This previous work was covered, for the most part, in the Michigan Geological Survey Progress Report #11, "The Geology of the Spruce River and Peshekee River Areas".

The field work in the Lake Michigamme area while far from complete has progressed to the stage where this report is considered advisable. Much work remains to be done, especially along the north limb of the iron formation eastward from Martin's Landing, as well as a considerable part of Sections 27 and 28 (T. 48 N., R. 30 W.). An extension of the mapping eastward to Humboldt is strongly recommended for the near future, and the mapping of the iron formation for at least a mile to the westward across most of section 35 (T. 48 N., R. 30 W.) is also advised, as the Negaunee iron formation extends in both of these directions beyond the limits of the present mapping.

Accompanying this report are the following maps:-

Map No.	Maps Accompanying Report	Scale
1	Lake Michigamme area	2" = 1 mile
2	Beacon to Lake Michigamme	10" = 1 mile
3	Section 4, T 47N., R. 29 W.	20" = 1 mile
4	Section 5, T 47 N., R.29 W.	20" = 1 mile
5	NE¼ Section 5, T 47 N., R. 29 W & adjacent area	40" = 1 mile
6	Section 6, T 47 N., R. 29 W.	20" = 1 mile
7	Section 10, T 47 N., R. 31 W.	20" = 1 mile
8	SW¼ T. 48 N., R. 29 W. (includes E edge 48-30)	4" = 1 mile
9	Section 19, T 48 N., R. 29 W.	20" = 1 mile
10	Section 21, T 48 N., R. 29 W.	20" = 1 mile
11	Section 28 & 29, T 48 N., R. 29 W.	20" = 1 mile
12	Section 30, T 48 N., R. 29 W.	20" = 1 mile
13	Section 31, T 48 N., R. 29 W.	20" = 1 mile
14	Section 32, T 48 N., R. 29 W.	20" = 1 mile
15	SE¼ Section 32, T. 48 N., R. 29 W.	40" = 1 mile
16	Section 33, R. 48 N., R. 29 W.	20" = 1 mile
17	T 48 N., R 30 W. (section through center) includes east part of 48-31	4" = 1 mile
18	S½. T 48 N., R 30 W.	4" = 1 mile
19	SW¼ T 48 N., R 30 W.	10" = 1 mile
20	SW¼ T 48 N., R 30 W.	10" = 1 mile
21	Section 1, T 48 N., R 30 W.	20" = 1 mile
22	Section 13, T 48 N., R 30 W.	20" = 1 mile
23	Sections 19 & 20, T 48 N., R 30 W.	20" = 1 mile
24	Section 20, T 48 N., R 30 W.	20" = 1 mile
25	Section 20, T 48 N., R 30 W.	20" = 1 mile
26	Section 21, T 48 N., R 30 W.	20" = 1 mile
27	Section 22, T 48 N., R 30 W.	20" = 1 mile
28	Section 23, T 48 N., R 30 W.	20" = 1 mile
29	Section 24, T 48 N., R 30 W.	20" = 1 mile
30	Section 25, R 48 N., R 30 W. (only part of Section)	20" = 1 mile
31	Section 26, T 48 N., R 30 W.	20" = 1 mile
32	Section 25 & 26, T 48 N., R 30 W.	20" = 1 mile
33	Section 27, T 48 N., R 30 W.	20" = 1 mile
34	Section 36, T 48 N., R 30 W.	20" = 1 mile
35	SE¼ T 48 N., R 31 W.	10" = 1 mile
36	Section 22, T 48 N., R 31 W.	20" = 1 mile
37	Section 23, T 48 N., R 31 W.	20" = 1 mile
38	Section 24, T 48 N., R 31 W.	20" = 1 mile
39	Section 25, T 48 N., R 31 W.	20" = 1 mile
40	Section 26, T 48 N., R 31 W.	20" = 1 mile
41	Section 27, T 48 N., R 31 W.	20" = 1 mile

The above maps show topography, outcrops and dip needle readings. Many of the sections were not completely mapped, the parts that appeared to carry no underlying iron formation being omitted in some cases, although the foot-wall series were usually mapped far enough back to be reasonably sure that the general character of the foot-wall formations did not change appreciably within the map area.

MAPPING METHODS

A true north and south line, accurate to within one unit in a thousand (2 paces to the mile), was established by Polaris observation near the base camp. This camp was located near the northeast corner of Section 26, (T. 48N., R 30 W.), about one-quarter mile west of the Peshekee River and a similar distance north of Lake Michigamme.

Dial compasses were used exclusively in the surveying, the instruments being equipped with either a movable sight bar or else carefully out sighting slots to permit accurate diagonal running. The most commonly used diagonal courses were those at angles such that the tangent was either 1:1 (45^o), 1:2 ($26\frac{1}{2}+^o$) or some other fraction convenient for plotting.

The dial compasses used for most of the work were constructed for latitude $46\frac{1}{2}^o$ which was the approximate latitude of most of the mapping. Other compasses at hand were for latitudes 47^o to 49^o, which while fairly satisfactory involved larger compass corrections.

Compass corrections were taken at intervals of a few days, usually on a Sunday or on some day when only intermittent sun made field work inadvisable. The corrections were obtained by setting up the instrument on the azimuth line and sighting carefully along the line. At about fifteen minute intervals throughout the day the dial was read and the corrections plotted as a curve. A series of such curves is shown in Plate II. A Jacob's staff support for the compass was used in practically all of the work. It was found that the instrument could be sighted along the azimuth line with an error not to exceed 1 unit in 500 (or about four paces to the mile). The dial could be read to the nearest half minute of time resulting in an error equivalent to less than five paces per mile.

Thus the error of any line carefully run in the field might be the error in the Polaris sight plus the error in setting the time on the dial plus the error in sighting through the instrument. If none of these errors happened to compensate each other, then the line might be off about 1/4" in azimuth, equivalent to an error of nearly 10 paces in a mile of traverse. In practice it was found that the lines could usually be relied upon to within 5 paces to the mile.

It was found impractical to use the center of the shadow of the gnomon thread as this shadow covered from 1 to 5 minutes of the sun dial graduations and the time could not be set with sufficient accuracy, except near noon when the shadow was the narrowest. Hence the practice of always using the left hand edge of the shadow was adopted and compass corrections were made accordingly. One curve in Plate II shows the corrections for each side of the shadow.

The method of taking compass corrections automatically took care of such factors as instrument inaccuracies, difference in time between the local meridian and the 90th, the time equation, watch regulations, refractions, etc. When the time equation was great enough to shift the correction curve entirely to one side of the zero line, it was generally advisable to set the compassman's watch back (or ahead) an amount sufficient to keep the correction curve fairly well centered.

When the corrections were large enough so that the curve showed a variation through the day of ten minutes or more (as the curves for May 11th, 1945 or June 6th, 1946), it was time to put in a new thread as such large variations from a straight line were apt to be due to fraying and stretching of the thread resulting in the gnomon being at an incorrect angle for the latitude. The new thread had to be carefully adjusted and a new set of corrections taken.

The compasses were sighted in just before going into the field each day and again immediately upon returning. Any deviation from the curve, other than the slight amount shown by the Ephemeris as due to the time equation, necessitated a check of the compassman's watch or of the curve, or both.

In the mapping, all distances were measured by pacing which was standardized under varying topographic conditions, care being taken that neither the type nor weight of the footwear was varied from day to day. The direct error in measuring distances by pacing was generally kept under 1% and this potential error was further reduced by double checking of much of the work by diagonal runs.

All pacing was corrected in the field to the standard of 2,000 paces to the mile which is the standard so long in use by the Michigan Geological Survey, timber cruisers and others. 1 pace = 1/2000 mile = 2.64 feet.

The various compassmen employed in the work took from 84 to 114 steps for 100 standard paces and had to adjust their pacing to the standard by taking an uncounted step at regular intervals, or else by counting a step twice every so often. The greatest adjustment necessary was by the compassman who took 118 steps to each tally of 100 paces, it being thus necessary to take two uncounted steps after each ten until the count of 100 was reached. In general it was found that the compass-men who had the most difficulty in pacing accurately and consistently were those who took the longest steps and were proud of it. Logs, roots, other obstructions and steep grades seemed to have a greater effect upon their accuracy than it did upon those with shorter legs. It is advisable to adopt an easy, steady gait so that the natural pendulum action of the legs can be best utilized.

The mapping was usually started at a section corner or a quarter post and a closed traverse run along two sides and a diagonal of a quarter section. Marked points were established at convenient intervals seldom more than 250 paces apart. These marked points usually consisted of three boulders placed from 12 to 18 inches apart and arranged in an equilateral triangle about the hole made by the Jacob's staff. Only rarely were any trees blazed and then only in the thicker brush where nearby saplings were barked with the chisel edge of the geological trimming hammer. These marked points were plotted on the maps as dots enclosed in a small circle.

The error of closure of this first traverse would be recorded and the marked points established either replotted to their correct position or else the points in the field would be shifted the few paces in the necessary direction if the error was verified by later traverses to them. After running this first triangle which included one-half of a quarter section, the triangle would usually be further subdivided into triangles 250 paces on a log and in many instances into still smaller ones. In addition, traverses were run to important geological points within the triangle so that they could be plotted with greater accuracy than could be obtained by estimating their location from the regular runs. The triangular arrangement of runs was not always closely followed in practice if an offset of some multiple of ten paces would avoid bad swamps, windfalls or other bad going without missing any valuable information.

Most of the old logging roads were traversed, not only to locate them accurately, but also to check up on their condition with their future value as a means of access to that particular area in view.

The work was all plotted in cross-section books ruled 6 lines to the inch. The scale most commonly used in the field was either 10 or 20 paces to the small square, except where considerable detail had to be mapped, in which case a scale of 5 (or even 1 pace or less) to a small square was used.

DIP NEEDLES

The dip needles used included four Lake Superior models made by Curley, and several older ones. The best results were obtained with a needle rebuilt from various old parts.

Every few days each of the operating needles was read at a selected number of marked points referred to as "dip checks". Curves and tables were made so that the readings taken with any one needle could be adjusted and plotted to a single standard. The dip checks were chosen to get a fairly complete set of readings from the lowest obtainable in the area to comparatively high ones, and with some where near equal intervals between them. As far as practical the dip checks were at points chosen where the underlying stratigraphy and structure were known.

The needles varied from each other in one or more of the following ways:- sensitivity, balance, friction, release, parallax, temperature change effects and less obvious factors. It seemed that nothing could be done to satisfactorily improve the sensitivity, but most of the other factors could be changed as conditions warranted.

The needles most commonly used were balanced to give readings between 0° and minus 50° at the lowest reading dip check, or from about 5° to 10° for most of the work in the field. The advantage of balancing the needles to give negative readings over low and even moderate anomolies increased their apparent sensitivity when crossing weak or deeply buried magnetic belts. This outweighted the disadvantage of dealing with so many negative readings.

The needles were read in the following manner, a standardized procedure being necessary to obtain uniform and reliable results.

Magnetic west was determined with the instrument held horizontally, then the needle was locked in the proper starting position as given in the adjustment curve for that particular needle. This was usually somewhere between 0° and -30°, and was chosen according to the balance and other characteristics of that needle. The reading at the end of the first up swing and the end of the following down swing were noted and if the bubble had not moved appreciably these readings were added algebraicly and divided by two. Some operators reading each swing to the nearest $\frac{1}{2}^{\circ}$ obtained readings to the nearest $\frac{1}{4}^{\circ}$ but it could usually be demonstrated that readings closer than $\frac{1}{2}^{\circ}$ could not be consistently duplicated and had little value unless such readings were the result of averaging three or more sets of readings.

The following conventions were used for recording fractions:- $7\frac{1}{4}^{\circ}$ was recorded as 7+, 7-3/4° as 8-, and $7\frac{1}{2}^{\circ}$ as 7. (a "7" followed by a dot). This resulted in greater speed and legibility.

The curves in Plates III,IV and V show how some of the different needles were balanced and their relative sensitivity in various parts of the range of readings. The steeper the curve the less sensitive is the needle.

The curves and the tabulations show the values, assigned to the different readings for each dip needle, and used on the 20 inch to the mile section maps. These values, while arbitrary, were assigned only after a great many composite curves had been constructed for all available needles. The plotting values were then so chosen that the curves for the various needles worked out with the least variation from a smooth curve. This seems to give a partially quantitative value to the adjusted readings.

The dip needles used each day were read at a dip check near the base camp just before starting into the field and were read again immediately upon return. The instruments were also read at one or more dip checks during the course of the days work and were frequently checked at marked points already plotted in previous work.

Any dip needle read at intervals during the day at the same spot usually showed a gradual drop until the sun had been up for about four hours, after which the readings remained practically constant, barring changes in the weather, until about four hours before sunset, at which time a gradual and steady rise would begin. This variation during the day might be as little as $\frac{1}{2}^{\circ}$ for some needles but a change of 2° to 3° was more common. Magnetic storms would sometimes cause such a sudden marked and erratic change in the readings that dip needle work would have to be suspended for a time. The daily dip needle work in the field had to be adjusted in accordance with the known (or sometimes assumed) variations that would occur daily between the time of leaving camp and the time of return. A fairly good check of this daily variation was usually had by checking back in the field work to nearby marked points from time to time.

No needles were adjusted in the field. If one of the instruments seemed to be giving erratic results and to be in need of adjustment, it was not used any more that day and the traverses were finished with one of the other needles. The faulty instrument was later checked at dip checks and if it still failed to function properly it was taken to camp and not used again in the field until the trouble was remedied and a new adjustment curve had been made for it.

In most of the field work, three dip needles, balanced quite differently were used. The dip needle man usually carried two needles and the geological mapper carried the other. Two or more of them were read on the more important marked points on the traverses. Only one needle was usually used between the marked points but occasionally two were read at precisely the same intervals and spots across the magnetic belts. This was done to see if additional information regarding the depth of overburden or the dip of the formation could be obtained through the magnetometer effect as described by C.O. Swanson in his article "The Dip Needle as a Magnetometer" in the Bulletin of the Society of Petroleum Geophysics, (Vol. 1, No. 1 of January 1936). While reliable results regarding the depth of overburden were probably not obtained it did seem that the direction of dip could often be deduced.

On days when clouds temporarily obscured the sun, or when the wind was gusty or shifting, or thunder storms approaching, it was found that the dip needle readings might fluctuate considerably. Under such weather conditions no field work was done where a variation of a degree or two in the readings seemed likely to have any particular significance.

It was also found that when a stop of a few minutes was made in a dip needle run, the instrument would often give readings at the last point differing as much as one or two degrees from the reading previously obtained there. In that case it would be necessary to repeat the readings at the point until the previous values were duplicated, or if that were not possible, then the readings for the rest of that run would be recorded with the change in value reported.

By reading at least two needles at each marked point, erratic behavior of any needle was usually promptly detected. Many of the reasons for a dip needle failing to function properly are still unsolved, but the following are some of the precautions that must be taken.

Do not brush the instrument against the clothing between readings as static may develop. Static is easily removed by breathing on the glass and allowing the evaporating moisture to carry off the static. Avoid jarring the instrument. Keep it well away from battery or starter cables in a car. Protect it from sudden temperature changes. Don't grind down on the release hard enough to damage the cone or wedge. And above all, don't ever make any adjustments on it during a dip needle traverse in the field.

Plate VI shows the magnetic profile across the entire Negaunee iron formation from the foot-wall Ajibik to the Bijiki iron formation, where much of the structure is visible in the outcrops.

Plate VII shows magnetic profiles across buried iron formation which is presumably dipping northward in profile "A", and southward in profile "B".

Early in the work it was realized that the dip needle man was usually completely busy taking and recording the magnetic readings and that the duties of his running mate had to be extended far beyond the ability of the usual compass man whose work is customarily confined to running straight lines and keeping the pacing. Thus a new division of work was necessitated with the dip needle man reading the needle at the necessary intervals and plotting the same. In addition he plotted only the marked points and such streams, roads, outcrops and other features that lay close to or were crossed by the traverse. That is, the dip needle man plotted only what was necessary in order to make sure that the magnetic readings were properly tied in with the outcrops and the rest of the mapping.

Instead of the conventional compass man, a geological mapper was employed who mapped in all of the topography, examined the outcrops, collected and trimmed specimens, located and established most of the marked points and kept the dip needle man located and on line. Except in 1944 and part of other years, someone with good eyesight and steady nerves who could be readily trained to operate a dip needle was found for the work. When no such help was available, then both the geological mapping and the dip needle work had to be done by one man, working alone, who had to establish marked points at closer intervals while mapping the topography and geology, with the magnetic readings being taken on the second trip over the traverse.

The following assistants worked as indicated.

Year	Geological Mapping	Dip Needle
1943	D.J. Seaman	D.J. Seaman
1944	- - - - - -	- - - - - -
1945	- - - - - -	A. Porturas
1946	- - - - - -	E. Kemp
	- - - - - -	Bruce Kennedy
1947	- - - - - -	Jerry Smith
	- - - - - -	Bruce Kennedy
	Bruce Kennedy	- - - - - - -

Stiff backed 5 x 8 inch cross-section books were used in the work. These had 128 pages ruled 6 lines to the inch. In the field each man plotted in his own separate book and all of the essential work was promptly transferred to an office book from which the large maps were made. Each office book had a general index on page 1 and a constantly growing key map on a scale of about 4 inches to the mile, on pages II to VI. This key map covered the part of the area as designated on the cover of the book and showed the pages in the book on which each part of the work was mapped to the regular scale. Each book was also cross indexed with the margins of each page indicating the pages on which the continuation of the mapping could be found. Pages 100 to 104 were usually reserved for the dip needle adjustment curves. Each office book contained the work from three or more field books.

The following office books are on file at the Michigan Geological Survey Office, Lansing, Michigan.

Designation of book and area		Year the work was done
B_1	Beaufort Mine area	Mostly in 1945
C_1	Champion and Beacon Area	1943, 1946 and 1947
C_2	Champion and Beacon Area	Mostly in 1947
F_1	Fence Lake Area	1945
M_1	Lake Michigamme Area, General	1943
M_2	Michigamme Area	1945
P_1	Peshekee River Area	1944
S_1	Spruce River Area	1944

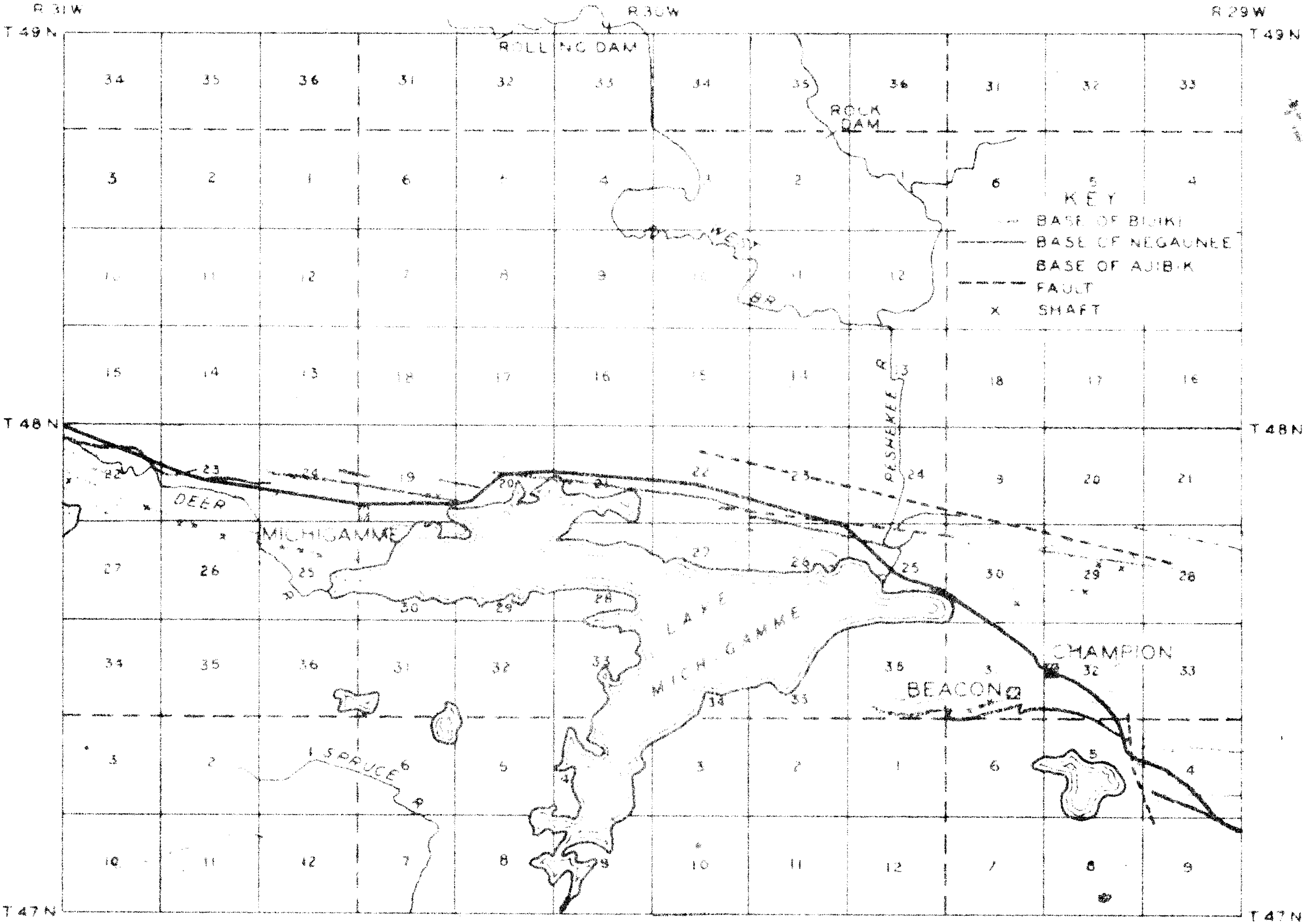
Specimens were collected of the different phases of each formation and were mostly of two types, trimmed hand specimens or channel samples. A few grab samples and a type designated as "selected average" were taken where channel sampling was not practicable.

The hand specimens were generally trimmed to a nearly uniform size of about 8 x 12^{cm} or a little larger than 3 x 4½ inches. They were carefully chosen only after a great many freshly broken fragments were carefully studied under a strong hand lens. The specimens were wrapped separately in the field and later had a small rectangular piece of adhesive tape attached near one corner. This label gave the township, range, section and the number of the specimen in that section in that order and in the following manner - 48-30 24#11.

The precise location of each specimen is shown in the field notes, in the office book and on the section maps. There is also a fairly complete hand lens description of the rock given in the supplement to this report. This description usually includes the strike and dip, and the approximate thickness or width of that sort of material as well as the character of the foot and hanging wall rocks.

The following list shows the number of each type of specimem taken in each section. The specimen, accompanied by labels, are on file at Michigan College of Mining and Technology.

Location	Hand Specimens mostly trimmed	Channel samples	Selected Average, etc.	Total
T. 47., R. 29 W.				
Section 4	6	0	0	6
" 5	26	4	0	30
" 6	22	20	5	47
T. 47 N., R. 30 W.				
Section 1	0	1	1	2
" 4	0	1	1	2
T. 47 N., R. 31 W.				
Section 1	0	2	2	4
" 10	0	0	0	0
" 11	0	0	0	0
" 12	14	0	0	14
T. 48 N., R. 29 W.				
Section 20	3	0	0	3
" 21	10	1	0	11
" 25	1	4	0	5
" 27	0	2	0	2
" 28	8	5	0	13
" 29	8	0	8	16
" 30	24	0	1	25
" 31	18	16	40	74
" 32	23	4	6	33
" 33	4	0	0	4
T. 48 N., R. 30 W.				
Section 11	19	2	0	21
" 2	10	0	0	10
" 12	10	1	0	11
" 13	28	2	0	30
" 19	6	0	0	6
" 20	21	4	0	25
" 21	3	7	0	10
" 22	7	0	0	7
T. 48 N., R. 30 W.				
Section 23	10	10	0	20
" 24	19	0	0	19
" 25	16	0	0	16
" 26	4	1	0	5
" 28	5	10	1	16
" 29	0	0	1	1
" 30	5	1	0	6
" 33	6	9	0	15
" 34	30	29	0	59
" 36	4	0	0	4
T. 48 N., R. 31 A.				
Section 22	16	0	0	16
" 23	10	0	0	10
" 24	11	0	0	11
" 25	5	0	0	5
" 26	4	0	0	5
" 36	2	0	0	2
T. 49 N., R. 30 W.				
Section 10	1	0	0	1
" 26	2	4	2	8
" 27	6	0	0	6
" 28	10	0	0	10
" 35	4	0	0	4
T. 49 N., R. 31 W.				
Section 36	4	0	0	4
TOTAL	445	140	68	653



KEY MAP-LAKE MICHIGAMME AREA

PLATE I

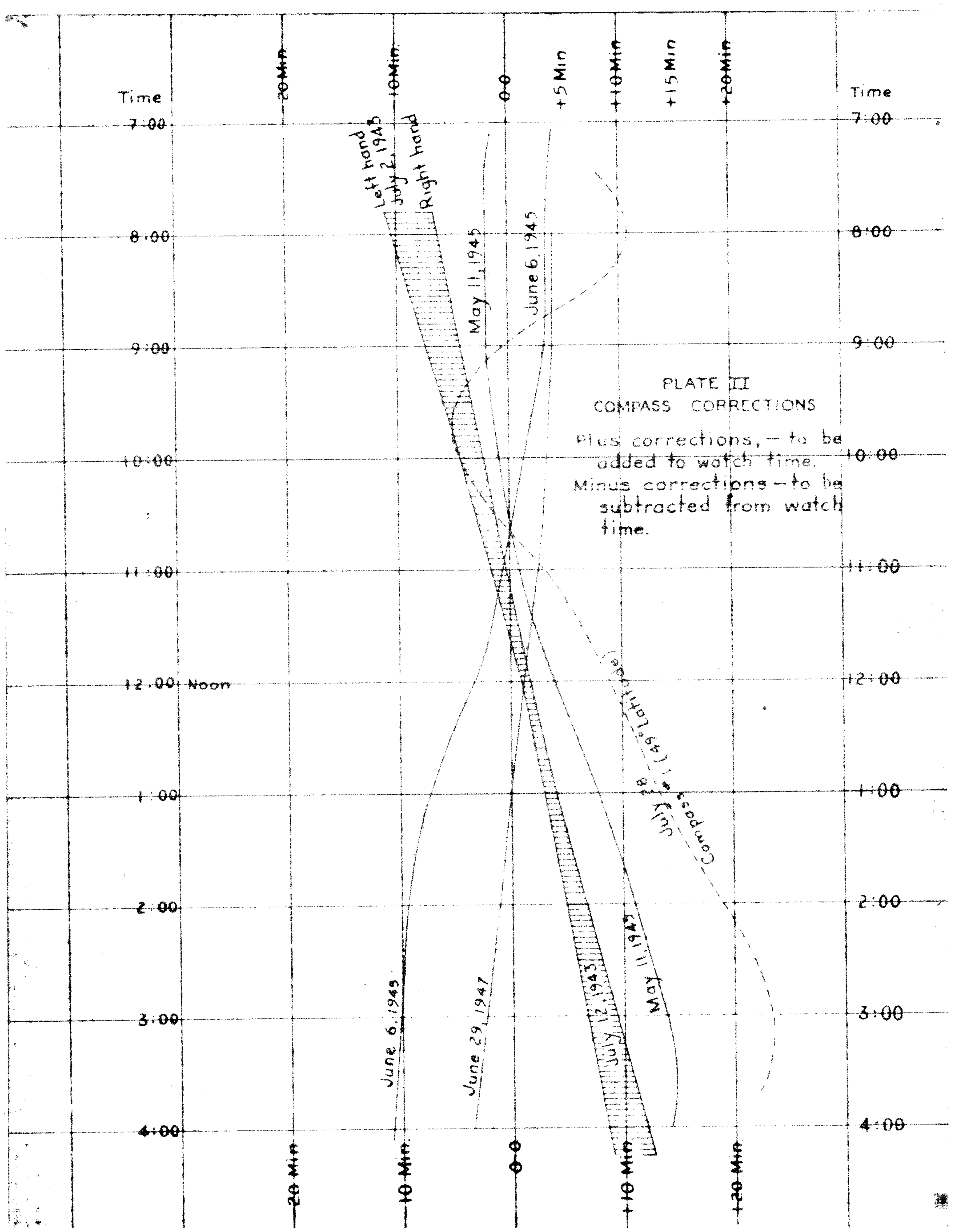


PLATE II
COMPASS CORRECTIONS

Plus corrections, — to be added to watch time.
Minus corrections — to be subtracted from watch time.

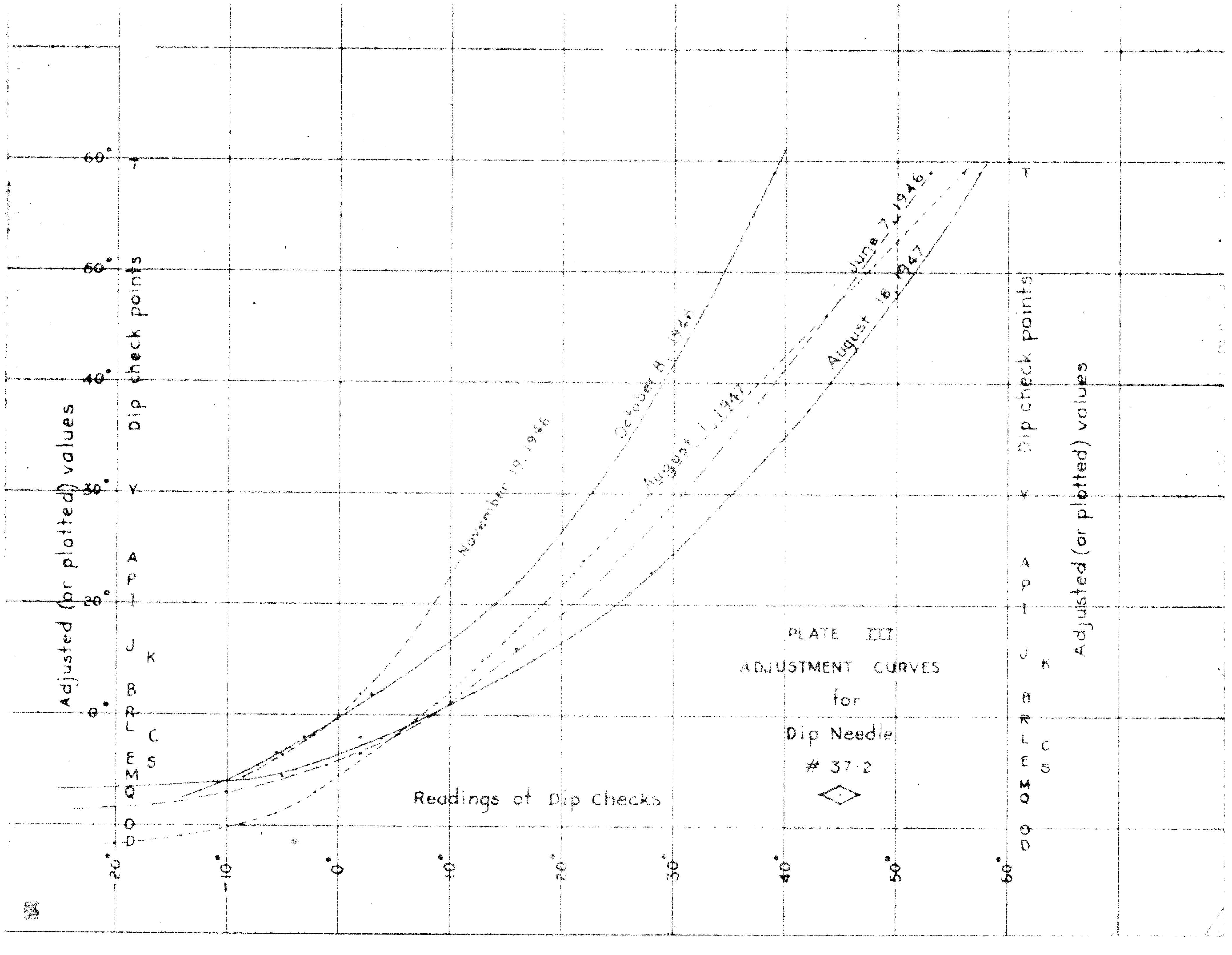


PLATE III
ADJUSTMENT CURVES
for
Dip Needle
37·2
Readings of Dip Checks
Adjusted (or plotted) values
Dip check points
November 19, 1946
October 8, 1946
August 1, 1947
June 7, 1946
August 18, 1947

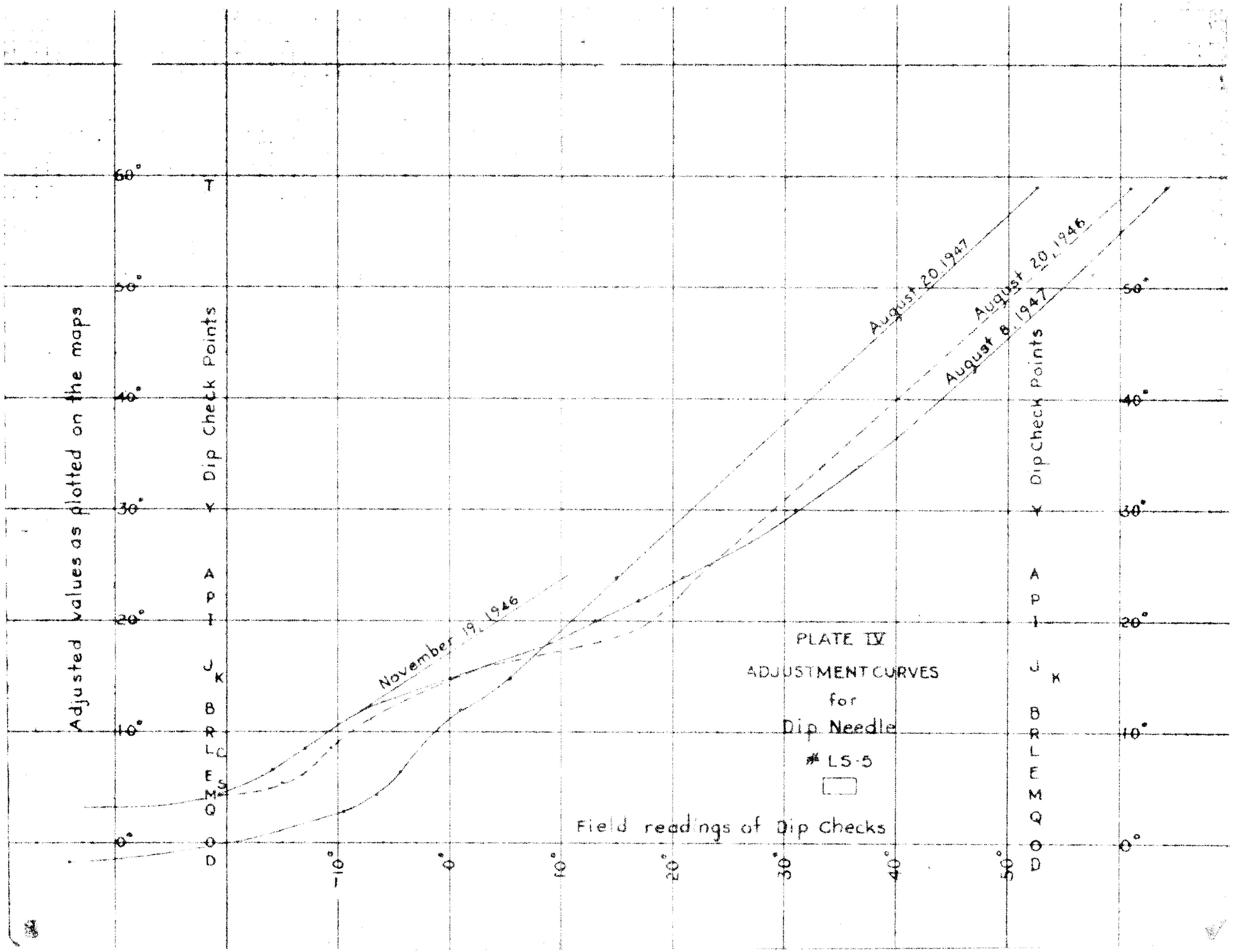
PLATE IV

ADJUSTMENT CURVES

for

Dip Needle

LS-5



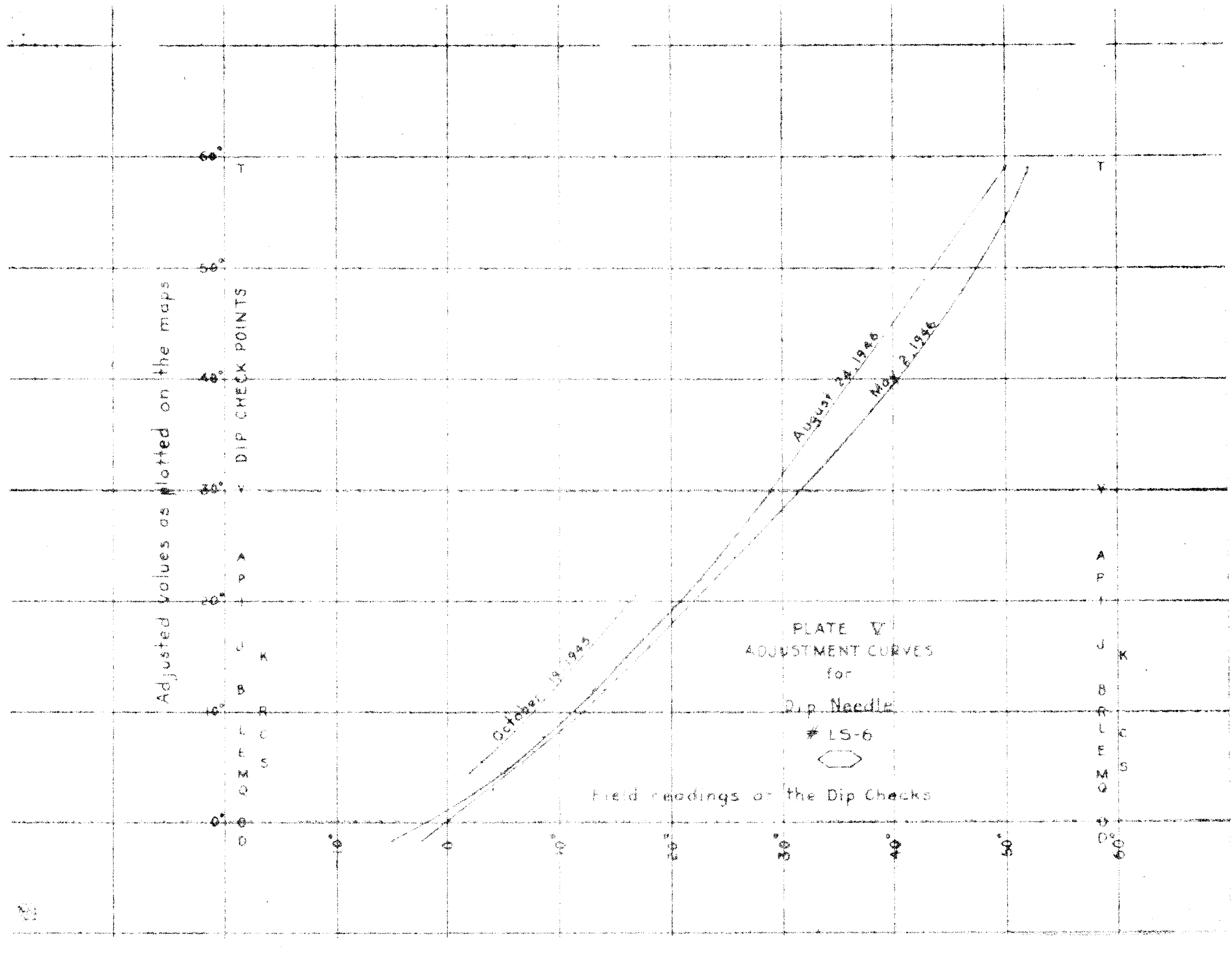


PLATE V
ADJUSTMENT CURVES
for
Dip Needle
LS-6
Field readings of the Dip Checks
Adjusted values as plotted on the maps
DIP CHECK POINTS
August 24, 1946
May 2, 1946
October 19, 1945
T
V
A
P
J
K
B
R
L
C
E
S
M
Q
D
0°
10°
20°
30°
40°
50°
60°

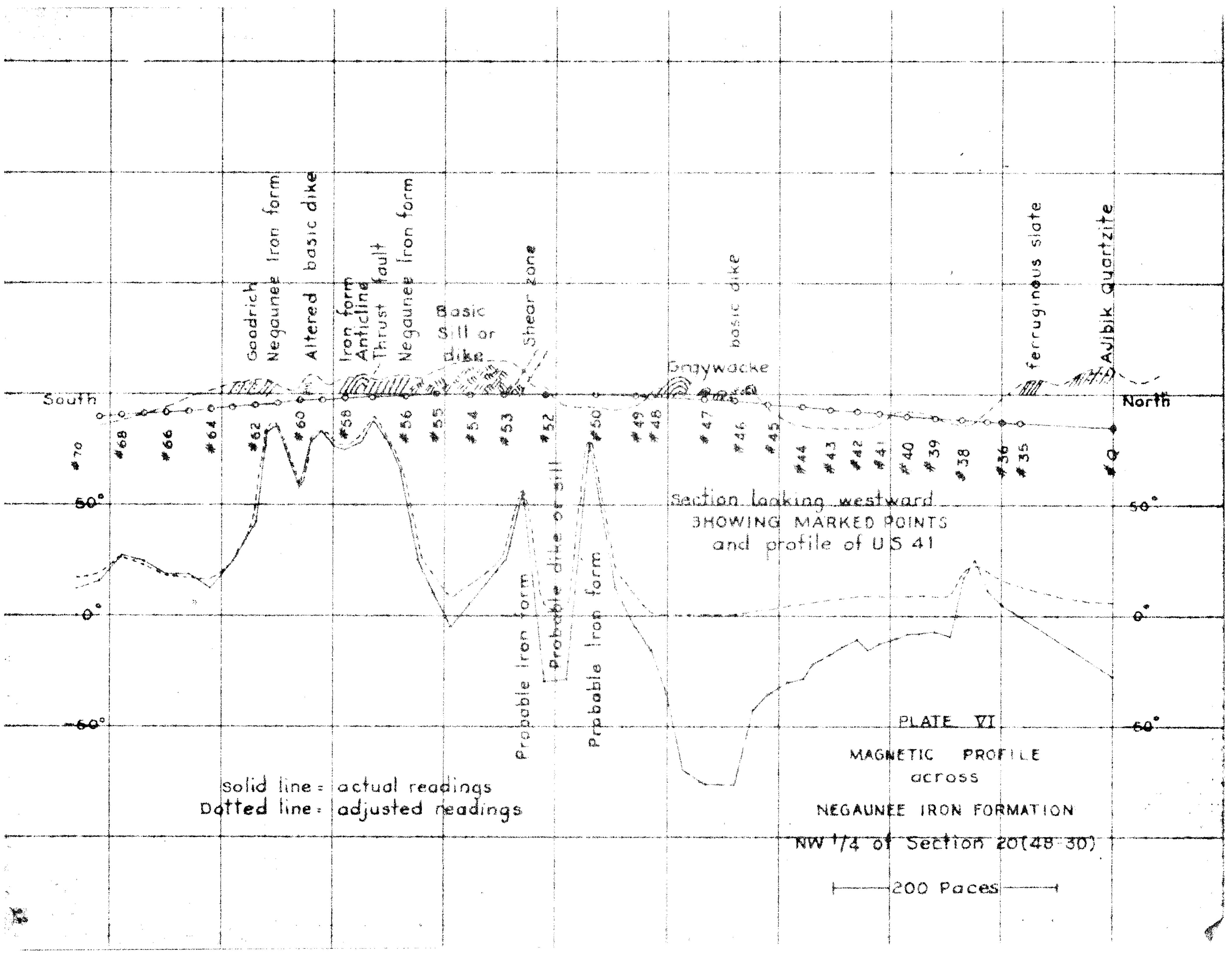
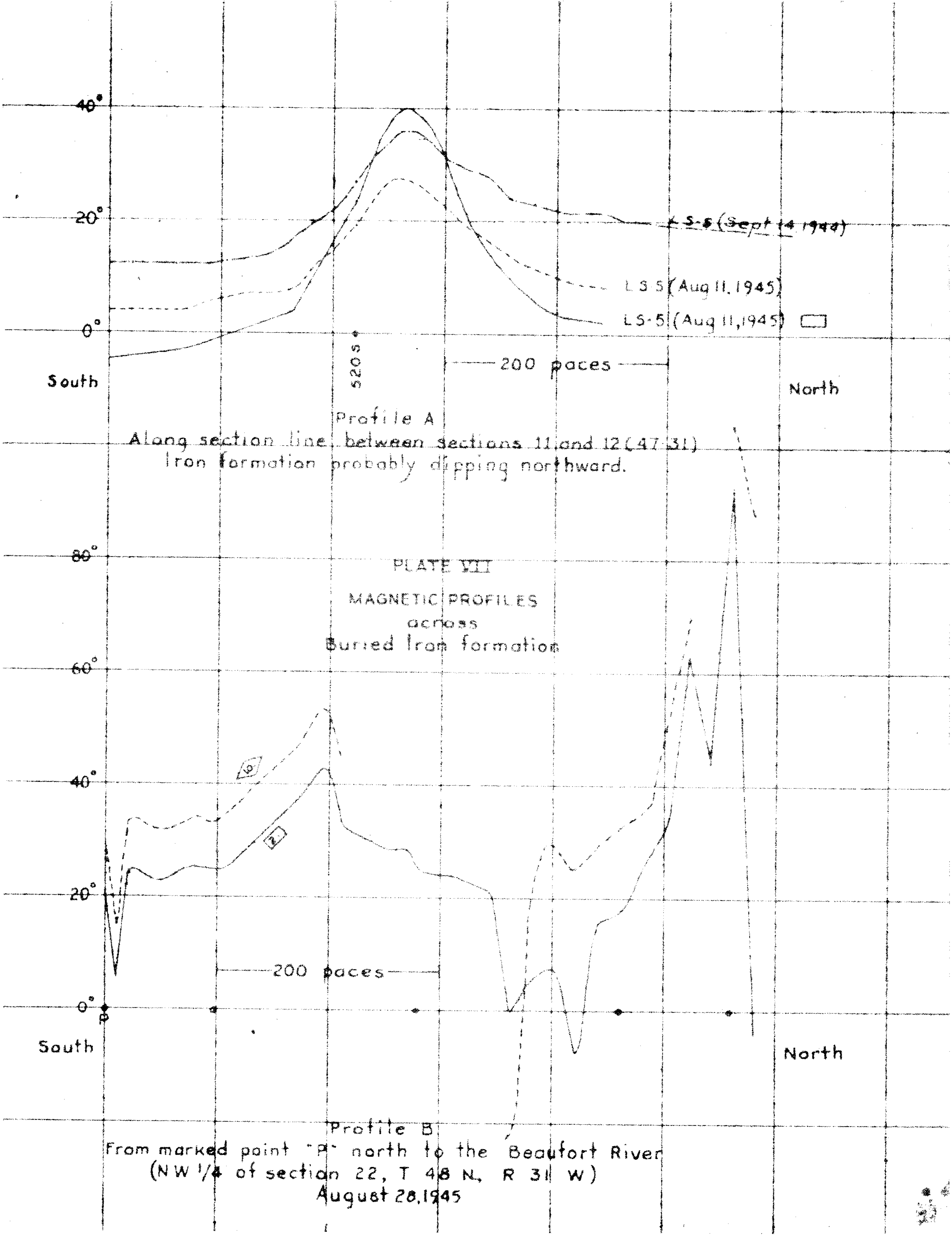


PLATE VI

MAGNETIC PROFILE
across
NEGAUNEE IRON FORMATION
NW 1/4 of Section 20(48-30)



Profile A
Along section line between sections 11 and 12 (47-31)
Iron formation probably dipping northward.

PLATE VII

MAGNETIC PROFILES
across
Buried Iron formation

Profile B
From marked point "P" north to the Beaufort River
(NW 1/4 of section 22, T 48 N, R 31 W)
August 28, 1945

T A B L E 1

Marked Points used as Dip Checks and listed in this Report.

Marked Point	Assigned Value	Location
T	59°	Sec. 20, (48-30). 460 paces E, 450 S of W$\frac{1}{4}$ post. Just N of 4ft boulder on S side of N turnout to roadside park. Negaunee iron formation dipping S.
Y	30°	Sec.22, (48-31). 530 paces W of E$\frac{1}{4}$ post. S of US 41, N of D.S.S. & A.RR and E. of Beaufort Road. Negaunee iron formation dipping south.
A	24°	Sec. 5, (48-29). 340 paces E, 340 S of N$\frac{1}{4}$ post. Negaunee iron formation dipping northeast.
F	22°	Sec.22, (48-31). 145 paces N, 245 E of W$\frac{1}{4}$ post. 1 pace west of corner fence post on north side of road. Bikiki iron formation dipping southward (?) near crest of anticline.
I	20°	Sec. 25, (48-31). 430 paces N, 600 E of W$\frac{1}{4}$ post. Square post on east side of trail across caved ground, just west of Imperial shaft. Bijiki iron formation dipping south.
J	16°	Sec. 26, (48-31). 550 paces N, 440 W of E$\frac{1}{4}$ post. South of road junction near Bass Lake. Bijiki iron formation dipping south.
K	15°	Sec. 32, (49-29). 420 paces N, 130 E of S$\frac{1}{4}$ post. South side of old road. Clarksburg tuff, near axis of anticline underlain by Bijiki and Negaunee iron formations.
B	12°	Sec. 26, (48-30). 100 paces S, 140 W of NE corner. Now abandoned due to enlargement of gravel pit. Negaunee iron formation dipping south-southwest.
B'	12°	Sec. 26, (48-30). 120 paces W, 150 S of NE corner. Nearly along the strike from point B and now used instead of point B. Negaunee iron formation dipping south-southwest.
R	10°	Sec. 25, (48-30). 1 pace west of 1/16 pin, which is 510 paces E, 500 S of NW corner. Negaunee iron formation dipping southwest. Now abandoned because of new high tension wires close by.

T A B L E 1 (Continued)

Marked Point	Assigned Value	Location
L	$8\frac{1}{2}^{o}$	Sec. 32, (48-29). 475 paces E of $S\frac{1}{4}$ post. Low on east shoulder of US 41 where line between 32 and 5 crosses. Bijiki iron formation, dipping northeasterly.
C	8^{o}	Sec. 25, (48-31). 210 paces E, 110 N of $S\frac{1}{4}$ post. Center of road junction (Spruce River and Cardinal Lodge Roads). Bijiki or Michigamme formation underlain by Negaunee iron formation. Considerable overburden. Iron formation probably in rolling syncline.
E	$6\frac{1}{2}^{o}$	Sec. 25, (48-30). 25 paces W, 25 S of center. North of US 41, W of Martin's Landing road. Bijiki iron formation, crumpled and with considerable overburden.
S	$5\frac{1}{2}^{o}$	Sec. 36, (48-31). Center of road junction, a few paces east of the $W\frac{1}{4}$ post. Michigamme formation underlain by the Bijiki and Negaunee iron formations at considerable (?) depth.
M	$4\frac{1}{2}^{o}$	Sec. 24, (48-30). 280 paces S, 20 E of center. SE side of junction of Huron Bay grade road and road to Martin's Landing Bridge. Ajibik, dipping southeast.
Q	3^{o}	Sec. 21, (48-30). About 410 paces E, 90 N of position of $W\frac{1}{4}$ post which was not found (probably in Ketchewn Bay). 410 paces east of the W line of the section, and on N side of US 41 by basic dike in steep south dipping Ajibik quartzite.
O	$(1^{o}$ $(0^{o}$	A few paces SW of point D. Marked point accidently destroyed in road improvements.. Point lost and not used since values are changing so rapidly within a few feet of the point that it can not be re-established with certainty.
D	$-1\frac{1}{2}^{o}$	Sec. 20, (48-30). 590 E, 140 S of $W\frac{1}{4}$ post. NW side of US 41 on small, sheared basic dike cutting an anticline of Ajibik mica graywacke.

TABLE 2

Adjusted Values	Dip Check	Needle # 37-2					Needle # L S-5				Needle # 29-5			Needle # L S-6		Needle # 16		Needle # 46-1				
	Dates	11-9-46	8-1-47	6-7-46	8-15-47	10-8-46	11-19-46	8-8-47	8-20-46	8-29-47	8-2-46	8-6-47	9-8-47	5-2-46	8-24-46	8-8-47	8-29-47	10-8-46	10-15-46	10-6-47		
59°	T		56	53	57.	39		64	61	52.	56	72		52	50	66.	52.	55			T	59°
30°	Y				35			31	29		23	34-		31.	29	32.		28?			Y	30°
24°	A	11	22	25			10.	21	22	15	20	25	18	25.	24	24	21.				A	24°
22°	P				28	16		17	20		18.	22.			22.	21.		19			P	22°
20°	I			21	26	14		13	18		17	20		21	20.	20.					I	20°
16°	J			16				3.	3.		10	17.		18	17	16					J	16°
15°	K		13					0	0.	5.	9	17				15.	9.				K	15°
12°	B	2	10	11	12	3	-8	-8.	-6.	1	5.	15	-2	14	14	12	5.	4.	-1.	7	B	12°
10°	R										3-				11						R	10°
8°	L							-13	-11			11.			9	6					L	8°
8°	C	-		3.	2	-3		-12.	-11		0.			7.	8.	5		-1			C	8°
6.°	E	-5	2.	2		-5.	-16	-16	-12.	-4.	-1	6.	-12		7.	1.	-2	-3.	-12	2	E	6.°
5.°	S			-1.	-2.	-7		-18	-15		-2.	4		6	6.	1					S	5.°
4.°	M	-9	0	-5	-7.	-8.	-21	-22	-23	-6.	-5	3		4	5	0.	-4.	-10	-16		M	4.°
3.°	Q		-2	-10		-13		-45	-27	-9.	-6.	-3.			4	-1	-7	-14	-24	-1	Q	3.°
-1.°	D		-20	-72	-70	-47		-110	-85	-34.	-25.	-20		-2.	-5.	-16		-90			D	-1.°

T A B L E 3

Dip Checks	Actual reading with different needles: Highest	Actual reading with different needles: Weighted Average	Actual reading with different needles: Lowest	Differences: Maximum	Differences: Weighted Average	Differences: Minimum	Sensitivity of Different Needles: % Maximum	Sensitivity of Different Needles: % Weighted Average	Sensitivity of Different Needles: % Minimum	Conversion Factor	Adjusted Readings: Late 1947	Adjusted Readings: Early 1947 & Late 1946	Adjusted Readings: Early 1946	Adjusted Readings: 1944,1945	Dip Checks
T	72	61	39								59°	59°	50°		T
				43	29	11.	140	100	40	1.00					
Y	35.	31	25								30°	31°			Y
A	35		10.	14	9	5.	175	110	50	0.91	24°	25°			A
P	28	22.	16								22°	23°	25°	21°	P
				7.	2.	1	230	115	50	0.87					
I	21	18	13								20°	20°	21°	15°	I
				9.	5	1.	240	125	50	0.87					
J	17.	13	3.								16°	16°	12°	11°	J
K	17		0	12	5	2.	300	135	60	0.75	15°	15°			K
B	17	8	-10								12°	12°	8°		B
R				15.	7	4	300	150	80	0.67	10°	8°			R
L	11.		-13								8°	5°			L
C	8.	1	-12.								8°	5°	5°		C
				5.	2.	1	370	165	90	0.60					
E	7.	-2	-16								6°	4°	3°	1°	E
				3.	2	0.	400?	175	95	0.55					
S	6.	-2.	-18								5°	3°			S
				8	2	0.	500	200	100	0.50					
M	5	-4	-23								4°	1°	2°		M
				23	4	0	1500	250	100	0.40					
Q	4	-10	-45								3°	1°	1°		Q
								400		0.25					
O				105	28	9	2300		200?		1°	0°	0°		O
								800		0.125					
D	-2	-40	-134								-1°	-1°	-2°		D

TABLE 4

GEOLOGICAL COLUMN* LAKE MICHIGAMME AREA

Era	Period	Formation	Rocks and events
		Recent	Muck, soil, etc.
		Post- Glacial & Glacial	Sand, sandstone, Gravel, conglomerate, hard pan, etc. Boulders, gravel, conglomerate, sand, etc.
			Faulting ?
		Keweenawan	Olivine diabase dikes
		Superior	Granitization, pegmatites, folding, faulting.
PROTEROZOIC		Sibley	Diabase dikes, partly uralitized.
PROTEROZOIC		Michigamme	Slate and mica schist Staurolitic mica schist Graywacke and quartzite Conglomerate
PROTEROZOIC		Clarksburg	Tuff, agglomerate, basic dikes, etc.
PROTEROZOIC		Bijiki	Slate, mica, schist Iron formation Slate,schist, graywacke
PROTEROZOIC	Iron Period	Goodrich	Quartzite and graywacke Conglomerate
PROTEROZOIC	Iron Period	Negaunee	Slate, schist Iron formation Slate, schist, graywacke, etc.
PROTEROZOIC	Iron Period	Ajibik	Quartzite, gneiss, etc. Conglomerate
PROTEROZOIC		Champion	Granitization, pegmatites, folding, faulting.
KOZOIC		Kona	Dolomite, slate, schist, gneiss.
KOZOIC		Mesnard	Quartzite, gneiss, slate, schist, etc.
KOZOIC		Kitcki	Slate, schist, Graywacke, gneiss, etc. Conglomerate
AZOIC		Laurentian	Pegmatite, granite, etc.
AZOIC		Keewatin	Chlorite and amphibole schist.

*See Geological Column and Correlation Chart in the Preliminary Report on the Lake Michigamme Area, Progress Report #10, "Strategic Minerals Investigations in Marquette and Baraga Counties, 1943", (Michigan Geological Survey).

STRATIGRAPHY of the LAKE MICHIGAMME AREA

KEEWATIN and LAURENTIAN.

Only a few small areas of what was presumed to be these older rocks were found in the area. The usual occurrence was in a plunging anticline or dome with the core exposed by erosion.

Near the southeast corner of Section 21 (T. 48 N., R. 29 W.) an outcrop 8 paces wide and 30 paces long consisted of antinolite schist (Specimen #6 from that section) cut by veinlets of pegmatite. This was in contact with and apparently overlain by a fragmental rock (Specimen #7) that contained abundant fragments up to a foot long of the actinolite schist. It was not proved whether or not the fragmental rock was a conglomerate, tuff or breccia, but it was believed that it may have been the Kitchi conglomerate, and if so, then the actinolite schist was almost undoubtedly Keewatin.

In Section 1 (T. 48 N., R. 30 W.) an outcrop about 20 paces long (north to south) and 10 paces wide consisted of chloritic schist (Specimens #5 and #7) dipping steeply south, cut by pegmatite (Specimen #6) also dipping steeply south, with a contorted, granitized graywacke above (to the south) and in direct contact with the chloritic schist.

More than five miles north of Lake Michigamme there are considerable areas of amphibole and chlorite schists and gneisses, part of which may eventually be proved to be pre-Kitchi, and probably Keewatin, in age.

About a mile south of the Champion Mine at Beacon, the granitized Ajibik lies unconformably across a nearly vertical, northward striking series of amphibole schists and gneisses which may be Keewatin, but seem more likely to be of Mesnard or Kitchi age.

Numerous areas of granitic and schistose rocks were encountered north of the iron bearing series, but in most cases detailed mapping and close examination showed that along the gneissoid banding they passed into recognizeable sediments the stratigraphic position of which could generally be determined. Thus it was concluded that a great deal, if not most, of the granitic areas formerly considered to be Laurentian or Keewatin were granitized Kitchi, Mesnard or Ajibik sediments. Sets of specimens were collected that showed practically all stages of the transition to the granitic rocks from the original graywackes and quartzites of each of the three series just mentioned.

South of the iron series, the granitic rocks were found to be almost entirely of sedimentary origin and definitely post-Laurentian in age. Thus the Keewatin and Laurentian rocks in the Lake Michigamme area can be dismissed with the statement that very few of these older rocks were identified, and that they do not make up any large proportion of the rocks in the area.

KITCHI

The basal member of the Kitchi series is a conglomerate such as is exposed near the middle of the northwest 1/4 of Section 20 (T. 48 N., R. 30 W.). This conglomerate contains abundant pebbles of chlorite or actinolite schist, subordinate granitic pebbles and a few pebbles of vein quartz in a matrix of quartz grains with considerable fine emphibole, chlorite and some biotite. The bottom of this conglomerate was not generally seen, though in a couple of instances (as mentioned under the occurrence of the Keewatin), it appeared to lie upon an older chloritic or amphibole schist. The comparative scarcity of granitic pebbles in it probably indicate that there was not much of the Laurentian granite nearby.

Above this conglomerate is a belt of graywacke with some slate that totals not less than 100 feet and probably has a thickness of several hundred feet, although in no instance could a thickness of more than about 150 feet be proved.

This graywacke formation was seen, studied and mapped in all degrees of metamorphism up to and including the quite completely granitized phase that may best be described as a quartz monzonitic gneiss. This gneissoid phase seems to constitute the bulk of the exposures covering most of the area, for five miles northward from the iron series, for the entire length of the area and for a considerable distance beyond, both easterly and westerly. In this fairly thick belt of granitized graywacke are thinner belts of dark biotite schist that are probably derived from the more slaty phases of the graywacke.

The strike of this great (Kitchi) graywacke series is about north and south in general, although locally it may be found striking in almost any direction if the noses of the folds are closely examined. The general structure is a series of close folds with both limbs dipping steeply westward. Many of the anticlinal crests have been plucked by glaciation, or otherwise removed, and it was necessary to map carefully and thoroughly in order to prove that this was not a series of tremendous thickness.

Because the Kitchi in the Lake Michigamme area is generally so highly metamorphosed that its original character and structure has been so obscured, it was thought advisable to revisit some less highly metamorphosed area where it might be studied in better detail. Good exposures of the Kitchi were found in a belt several miles long on the north side of the Marquette basin between Negaunee and Marquette. This belt is exposed fairly well at frequent intervals from a short distance northwest of the west 1/4 post of Section 32 (T. 48 N., R. 26 W.) eastward to beyond the south 1/4 post of Section 29 (T. 48 N., R. 25 W.). Westward from Section 32 the Kitchi has been subjected to more and more faulting, folding and metamorphism, gradually assuming the character exhibited so generally in the Lake Michigamme area.

In Section 29 (T. 48 N., R. 25 W.) the base of the Kitchi is a conglomerate, dipping steeply south, several feet thick and exposed almost continuously for several hundred paces. This conglomerate lies uncomformably upon crumpled chlorite schist and contains pebbles of the following material, listed in decreasing order of abundance.

Granite (or granitic material) containing from 15% to 40% quartz, feldspar (about twice as much alkalic as calcic), considerable hornblende altered more or less to chlorite.

Vein quartz.

Felsite and rhyolite.

Dark, basic chlorite and amphibole schist.

The basic schist fragments undoubtedly came from the immediately underlying Keewatin which is exposed for a considerable distance to the northward.

The granitic material, rhyolite and felsite seem identical with the material in so many of the east and west dikes that intrude the Keewatin, becoming larger and more numerous to the northward until a granitic mass several hundred acres in extent is reached near the Dead River north of Marquette.

Above the conglomerate at the base of the Kitchi was found a few feet of slaty graywacke. Next was a flat area about 100 feet wide with few outcrops, all of which were slate. Then about 200 feet of graywacke with occasional beds of brownish to pinkish quartzite each only a few inches thick. Next a slaty graywacke, 10 to 30 feet thick, succeeded by a somewhat pinkish quartzite several feet in exposed thickness, above which was more slaty graywacke.

A gap of about 100 paces, with no significant change in topography, lies between these last exposures of slaty graywacke and the sericitic quartzite near the base of the Mesnard which outcrops along the north side of Mud Lake (Lake Enchantment) on the south line of the section. The basal Mesnard conglomerate, outcropping a few hundred feet to the westward, strikes into about the middle of this 100 pace gap.

On Section 32 (T. 48 N., R. 26 W.) the local top of the Kitchi is a slate member unconformably below the basal Mesnard conglomerate containing well rounded pebbles of the following material, listed in the approximate order of their decreasing abundance. Vein quartz, quartzite, graywacke, chert, slate, granitic material, soft basic schist.

Only the top few feet of the Kitchi slate underlying this conglomerate was here exposed along the south edge of a swamp.

No pebbles of any sediments were found in the conglomerate at the base of the Kitchi, and the chert that has been reported from there was more likely observed in the near by Mesnard conglomerate which may have been mistaken for the Kitchi. It was perhaps because of thus confusing the two conglomerates that the entire Kitchi series east of Negaunee was mapped with the Mesnard in Monograph XXVIII. Westward from Ishpeming the entire Kitchi was mapped as the Kitchi schist phase of the Keewatin in the same Monograph. Thus the entire Kitchi period seems to have been lost and is not usually described in the literature.

The term "Kitchi", first used in Monograph XXVIII was a good choice, it being an Objibway term signifying "great" and fits in well with the occurrence of a great graywacke (schist or gneiss) series between the older granite and the Mesnard.

The presence of chert pebbles in the conglomerate at the base of the Mesnard while none were observed in the Kitchi conglomerate, and no cherty formations evident in any of the exposures of the Kitchi stratigraphically between the two conglomerates, indicates that part of the top of the Kitchi, eroded before the deposition of the Mesnard series, may have included one or more cherty members. No conclusions were drawn as to the probable thickness of the eroded part of the Kitchi, nor as to whether the chert fragments in the Mesnard conglomerate represented eroded cherty dolomite, other chert bearing sediments or merely chert veins in the Kitchi.

Because of the prevailing steep dips in the Mud Lake section and the likelihood of considerable faulting, folding and erosion that might seriously affect estimates of the true thicknesses, the formations that constitute the Kitchi are given below, with their thickness listed between what are considered probable limits.

	Minimum		Maximum	
Cherty formation, locally eroded	? feet		??? feet	
Slate	10	"	100?	"
Slaty graywacke	50	"	200	"
Quartzite	10	"	50	"
Graywacke	150	"	500	"
Slate	50	"	100	"
Graywacke & Slaty graywacke	10	"	50	"
Conglomerate (no pebbles of sediments)	3	"	20	"
	300	" to	1200	"

MESNARD

A considerable amount of quartzite, usually more or less granitized, was encountered north of Lake Michigamme. The exposed thickness was in some places more than 40 feet but though the mapping showed that it was pre-Ajibik and younger than at least part of the Kitchi, it was difficult in most places to prove whether it was Mesnard or Kitchi. The quartzite at the Rock Dam on the North Branch of the Peshekee River, near the north line of Section 2 (T. 48 N., R. 30 W.) appears to belong to the Kitchi series as no definite break was found between it and the quartz monzonitic gneiss phase of the granitized Kitchi graywacke underlying it. On the contrary, the quartzite in the center of a syncline exposed in a bluff south of and below the Ajibij in Section 23 (same township) is thought to be a remnant of Mesnard as it appears to overlie a considerable thickness of Kitchi graywacke in which are beds of quartzite material, that are more thoroughly metamorphosed and contain more basic material than the presumed Mesnard in the axis of the fold.

It is apparent, though, that in general the Mesnard was either not deposited over most of the area north of Lake Michigamme, or if it was formerly present, it was mostly removed during the pre-Ajibik erosion interval, as where the Ajibik is found it usually lies directly upon the Kitchi graywacke.

KONA

No formation considered to be Kona was found in place although an occasional fragment that resembled Kona dolomite was found in the Clarksburg tuff which might indicate that the Kona had been present in some parts of the area. In view of the extreme stage of metamorphism of much of the quartzite as late as the Ajibik, it would seem that the Kona would generally be metamorphosed beyond ready recognition. Furthermore, with so little of the usually thick Mesnard left after the pre-Ajibik erosion, most of the Kona would likewise have been removed.

CHAMPION PEGMATITES, GRANITIZATION, FOLDING AND FAULTING.

The pre-Ajibik formations were squeezed into generally north and south striking folds and underwent varying degrees of metamorphism. A considerable amount of thrust faulting accompanied the folding. Pegmatites striking in various directions but predominently north and south are abundant in the Kitchi series. These pegmatites have not always been distinguished from those of a later (Superior) series in the areas where no Ajibik or other formations were present. A study of the pegmatites where the age could be established indicated that the Champion pegmatites generally lacked the molybdenite, beryl, and andalusite that are fairly common in the Superior pegmatites. They also probably contain less apatite.

The folding that accompanied the Champion Revolution seems to have resulted in the elevation as well as the crumpling of the old sea bottom formations such as the Kitcki, resulting in the north shore line of the inter Ajibik sea being moved southward, in some places several miles.

Although the Champion granitization may have been accompanied by some commercial mineralization, no direct evidence of it was found, and the pegmatites and quartz veins that seem to be of this age appear to be nearly or totally lacking in mineralization.

AJIBIK

The basal Ajibik conglomerate, only a few feet thick in the few places where seen, contains well rounded and well sorted pebbles of quartzite, quartz monzonitic gneiss (granitized Kitchi), other gneissoid and granitic fragments, pegmatite and feldspar pebbles, and a few small flat pebbles of basic schists. The matrix, composed mostly of quartz grains, contained fine chlorite or other dark scaly material, and in places had a small percentage of finely disseminated dark material in irregular spots or mottlings from 1 to 2^{mm} across. There were also granules $\frac{1}{2}^{mm}$ in diameter of iron hydrate or of some material altering to

"Limonite". These brownish granules were more abundant in the upper, finer part of the conglomerate and in the overlying quartzitic slate and quartzite. Specimen #9 from Section 21 (T. 48 N., R. 29 W.) shows such a conglomerate and specimen #8 shows the gradation toward the overlying quartzitic slate. The conglomerate and quartzite were here dipping steeply southward and lying across the northwesterly striking Kitchi graywacke and gneiss. Both the conglomerate and the bottom of the overlying quartzite were considerably granitized at this locality.

Above the basal conglomerate a quartzitic slate a few feet thick grades up into a vitreous quartzite. This quartzite, including the quartzitic slate at the bottom showed a maximum width of about 260 feet in sections 20, 21 and 22, (T. 48 N., R. 30 W.). The dip varied from steep north, through vertical to 60° southward. Thrust faulting and close folding seen in the vicinity would indicate that the true thickness might be a little less than 100 feet. This quartzite appears to thin out to the westward and perhaps also to the southward, but the rather scanty exposures available within the map area do not conclusively show this.

There is very little of the Ajibik exposed east of the center of Section 22 (T. 48 N., R. 30 W.). Westward from this place there are frequent outcrops for the next two or three miles. Most of the exposures are of a nearly white, vitreous phase, but in three places in Sections 21 and 22, (T. 48 N., R. 30 W.) where exposures near the bottom of the quartzite were available, the quartzite near the base was seen to be somewhat granitized.

The Ajibik quartzite is succeeded by more or less ferruginous slate, graywacke with considerable biotite and chlorite, and then by more slate, much of which is quite ferruginous. The biotite and chlorite that is so abundant in some beds of the graywacke, probably came from the distant Hemlock volcanics. This biotite and chlorite is in a number of beds totalling several feet in thickness in a horizon probably about 20 feet thick. It may represent fine ash that either fell into the sea at that place or else was washed down from the old land area just north of there at various times during the following years.

The total distance across the Ajibik series, with the dip steeply to the south, varies from 500 feet to more than 1500 feet, with the quartzite member comprising from 20 to 40% of this total. The true thickness is much less than the width,as four separate anticlines were mapped in an area where the width was about 1200 feet. It is probable that more folds were missed than were mapped, so it appears that the true thickness of this entire series of conglomerate, quartzite, graywacke and slate might be less than 300 feet, and is probably not more than 600 feet.

South and southwest of Champion the southwest striking Ajibik outcrops abundantly across a belt nearly a mile wide with most of the dips steep to the northward. The series here strikes southwesterly and lies across the truncated ends of an older series that strikes between north and northwest. The mapping was not carried far enough into this older series to prove whether it is Mesnard, Kitchi or older, but several specimens taken were strikingly similar to some of the granitized Kitchi on the north side of the trough. Other phases of this older series seemed more like some phases of the granitized Mesnard quartzite that had previously been studied on the south side of the Marquette Range between Marquette and Palmer.

In the mile wide belt of Ajibik south of Champion the true thickness of the Ajibik is again but a small fraction of its width, as four major anticlines and several minor ones were mapped. The folds were tightly closed with both limbs in general parallel and dipping 60° to 80° northward. Swamps occupy most of the narrow valleys between anticlines. A swamp also usually lies between the Ajibik quartzite and the iron formation to the north, in which swampy area a few low outcrops of slate were found.

Pegmatites, mostly striking about parallel to the axis of the folds, are abundant near the crests of the anticlines of Ajibik quartzite south and southwest of Champion. These pegmatites are younger than any of the metamorphosed rocks in the vicinity and will be described later.

Southeast of Champion the Ajibik quartzite, mostly quite thoroughly granitized, strikes more nearly southeasterly with steep northeasterly dips.

The Ajibik quartzite on the south side of the trough from Lake Michigamme to the eastern limits of the map area shows all stages of granitization,and dozens of trimmed specimens were taken showing almost every phase from the vitreous Ajibik to the most thoroughly granitized material.

Some of the progressive stages in the granitization seem to have been the development or addition of sericite or other fine mica; enlargement of the quartz grains by silica deposited around them in parallel position, partly to completely masking the granular character; development of secondary feldspar in some of the small irregular sericitic areas, and finally such a complete recrystallization that the rock becomes practically indistinguishable from what is usually called a granite. The feldspar pseudo-phenocrysts often attain a length of 15 to 20^{mm} and in some places they have been found more than 50^{mm} in length, and the rock becomes what is often called a granite porphyry.

C.A. Lamey has described similar granitization effects along the south side of the Marquette Range, in several articles including one on "Some Metamorphic Effects of the Republic Granite" in the Journal of Geology, Vol. XLII, 1934, and in another acticle on "The Palmer Gneiss" in the Bull. Geol. Soc. America, Vol. XLVI, 1935.

T.T. Quirke has discussed the granitization on the north shore of Lake Huron in his article on the "Killarney Gneisses and Migmatites", Bulletin, Geological Society of America, December 30, 1927.

THE NEGAUNEE IRON FORMATION

EXTENT AND THICKNESS:

Southeast and east of Beacon abundant outcrops of the Negaunee iron formation are found for about one mile along the strike. In a few places the overlying Goodrich can be found either in contact with the iron formation or within a few paces above it. The extreme bottom of the iron formation was not found in any of the outcrops, but the gap between exposures of the iron formation and the foot-wall formations is less than 100 paces wide in some places and the dip needle readings drop off rapidly to a nearly uniform low near the iron formation side of this gap. Thus the lower limit of the iron formation can usually be determined to within quite close limits.

In this stretch of the iron formation its width varies from about 500 feet to nearly 1,000 feet. Near the west line of Section 32 (T. 48 N., R. 29 W.) where the width is about 500 feet the formation dips 60° or steeper and is only moderately crumpled. Enough exposures are available to make sure that there are no intrusives more than a few inches in width present. One small fold was mapped in this area, and this, together with the visible crumpling and faulting would exaggerate the thickness by probably not less than 50 feet nor more than 150 feet, so the true thickness here is probably close to 400 feet.

Near the south 1/4 post of Section 32 (same township), the iron formation has a width of 800 to 900 feet but there is little room for doubting that the greater width of the formation is due almost entirely to the difference in structure as considerable folding can be seen here and many of the dips are rather flat with some outcrops showing a southward dip for a short distance.

Another wide place in the iron formation was seen in the SE$\frac{1}{4}$ of the SE$\frac{1}{4}$ of Section 31 (T. 48 N., R. 29 W.). Here there is not only a great deal of folding, but there are also at least two dikes or sills having a total combined width of more than 260 feet.

In the western part of the map area the Negaunee iron formation is quite well exposed along the northern limb from near the center of Section 22 (T. 48 N., R. 31 W.), eastward into Section 20 (T. 48 N., R. 30 W.). The width varies from 300 to nearly 500 paces (or from about 800 to 1300 feet). In each traverse across it, one or more large basic intrusions and considerable folding are to be seen.

Just east of the Michigamme Mine the width is nearly 400 paces, or about 1,000 feet, from the Goodrich conglomerate at the top of the sudden drop in dip needle readings about 40 paces from the exposed foot-wall slates. Two hundred and fifty feet of this distance is across outcroppings of a basic sill or dike and another basic dike is exposed for a width of about 50 feet. There are other narrower dikes,and one anticline in the iron formation is exposed that is about 75 feet across. This leaves only about 650 feet for the net width of the iron formation with a dip generally between 60° and 80° southward. There is, of course, the strong probability that there are other folds that were not seen and also probably more dike material than can be seen in the outcrops. Furthermore, the edge of the larger dike is closely sheared for a width of several feet and other indications of thrust faulting were noted. Taking all of this into consideration it is believed that the true thickness of the iron formation here is not less than 300 feet nor more than 500 feet, or about the same as the thickness near Champion on the south side of the trough.

Eastward from Section 20 (T. 48 N., R. 30 W.), the Negaunee iron formation was not found to outcrop within the map area, but the formation could be followed quite easily and accurately with the dip needle. The magnetic work indicated that it continued practically unbroken to near the Peshekee River nearly four miles further east. There it appeared to bend, or be faulted to the northward and continued as a strong magnetic belt eastward past the southeast corner of Section 20 (T. 48 N., R. 29 W.) near Martin's Landing. From there eastward there are some gaps in the belt due to faulting in two places and in another locality probably due to an overlap of younger formations. A sufficient amount of detailed work has not yet been done along this part of the north limb.

A great deal of magnetic work was done across the outcrops of the iron formation so that the dip needle readings could be better interpreted across the buried parts of the formation. No two lines of dip needle readings across the outcrops checked very close as regards the location of the highest readings nor the differences between readings taken at equal intervals. This was to be expected considering the great difference in structures to be seen with a few paces along the strike. However, while the readings on successive traverse differed radically each traverse usually showed a rapid rise near the base of the iron formation, then a more gradual rise until a peak was reached, from which there was a gradual decrease in readings. In the more closely folded and faulted areas, or where the formation was cut by dikes or sills, there would usually be more than one peak reading. Plate VI shows a magnetic profile across the entire Negaunee iron formation a short distance east of the Michigamme Mine.

The following list gives the maximum adjusted reading in each of 12 complete traverses across the iron formation where it outcrops south of Champion. The traverses were about 200 paces apart and are recorded below in order from near the west end to near the east end.

65°, 24°, 75°, 27°, 50°, 51°, 77°, 60°, 40°, 23°, 29°, 40 °.

The iron formation was mapped magnetically both eastward and westward from the mile long exposures near Beacon and Champion. The following maximum adjusted values were obtained in crossing the unexposed iron formation in Section 4 (T. 47 N., R. 29 W.), the traverses being spaced at nearly equal intervals and each one east of the preceding one.

25°, 22°, 23°, 21°, 20°, 18°. The adjusted value of the readings in the foot-wall formations in each case were about 3°.

Westward from the eastern part of Section 31 (T. 48N., R. 29 W.) the following maximum adjusted values were noted, each traverse being farther west than the preceding one. 65°, 60° (near Champion Mine cave-in), 55° (near #5 shaft), 44° (near #4 shaft, 36° (near #7 shaft), 20°, 22°, 27°, 25°, 27°, 23°, 20°. The last six of these readings were in Section 36 (T. 48 N., R. 30W.).

In the entire mapped length of this belt of the Negaunee iron formation, which was about four miles long, including the mile long belt of outcrops, the formation appeared to vary from 400 to

1200 feet in width. The narrowest part was about a half mile west of #7 shaft where, though the Negaunee iron formation did not outcrop, both the overlying Bijiki and the underlying Ajibik were found in place for a considerable distance. The dips increasing toward the foot from the 70° of the Bijiki to about 80° for the Ajibik. It was concluded that the Negaunee iron formation was not much narrower than its apparent width unless unseen faulting or intrusions were present to make the true thickness less than the apparent thickness there of about 350 feet.

Nowhere within the map area was any evidence found indicating that the thickness of the Negaunee iron formation had been appreciably effected by pre-Goodrich erosion. All evidence pointed to the erosion interval below the Goodrich being of short duration and only the crests of anticlines and upthrust portions of the Negaunee were appreciably modified by the erosion.

CHARACTER of the NEGAUNEE IRON FORMATION

The Negaunee iron formation in the Lake Michigamme area is predominantly of the grünerite-magnetite phase except near the top where the formation was oxidized before metamorphism. This upper part, ranging from 0 to 50 or more feet in thickness is apt to be either the magnetite-granular quartz phase or a jaspilitic phase depending upon the degree of metamorphism it has undergone.

Because several phases of the iron formation, more or less common elsewhere, are comparatively rare in this area, it was considered advisable to study the character of this formation in other parts of the Marquette Range before any conclusions were drawn as to the relations and significance of the phases to be seen near Lake Michigamme.

Many different types of the iron formation were found and carefully examined in the field in various parts of the Marquette Range and hundreds of specimens were collected and studied, together with the record of their field occurrence. It became apparent that the different phases of the iron formation had been derived from either original cherty iron carbonate, from "greenalite", or from both.

The following tabulation shows the apparent relations between the different phases of the iron formation. A sufficient number of specimens were taken so that nearly all gradations between the types listed were represented.

The horizontal arrows in the table point to oxidation products of the original cherty iron carbonate (or of the "greenalite") and the vertical arrows show some of the progressive stages in the metamorphism.

COMMON TYPES of IRON FORMATION

(1) Cherty iron carbonate → (2) Chert, iron carbonate & "limonite" → (3) Ferruginous chert or Siliceous "limonite" (or earthyhematite)

(1) Cherty iron carbonate
↓
(1a) Recrystallized carbonate & chert (± magnetite)
↓
(4) "Grünerite", magnetite & granular quartz

(2) Chert, iron carbonate & "limonite"
↓
(4a) Granular quartz (or chert), specular hematite (or magnetite) & "grünerite"
↓
(4b) Granular quartz, magnetite & "grünerite"

(3) Ferruginous chert or Siliceous "limonite" (or earthyhematite)
↓
(5) Jaspilite
↓
(6) Magnetite (± specular hematite & granular quartz

- -

(7) "Greenalite" → (8) Granular ferruginous chert or Granular Siliceous "Linomite" or earthy hematite

(7) "Greenalite"
↓
(4c) "Grünerite", magnetite & granular quartz (or chert)

(8) Granular ferruginous chert or Granular Siliceous "Linomite" or earthy hematite
↓
(6a) Magnetite (or hematite) & granular chert (or quartz)

Some of the localities on the Marquette Range where each of the above listed types of the iron formation are unusually well exposed in the outcrop:-

(1)	Cherty siderite	Railroad cut between Athens and Negaunee Mines, in Negaunee. North Volunteer Pit, Palmer.
(1a)	Recrystallized cherty siderite	Near Barnum shaft, Ishpeming.
(2)	Oxidized product	Same localities as (1).
(3)	Ferruginous chert or Siliceous "limonite" (or earthy hematite)	Southeast of the Lucky Star shaft, Negaunee. Chicago & Northwestern Railroad cut near Mary Charlotte Mine, Negaunee. Many of the mine dumps around Negaunee and Ishpeming.
(4) (4a) (4b)	"Grünerite", magnetite & granular quartz	West end of main pit, Spurr Mine, Michigamme.
(5)	Jaspilite	Jasper Hill, Ishpeming.
	("fragmental" phase)	South edge of Palmer, either side of M-35. 1½ miles west of Spurr Mine, US-41.
(6)	Magnetite and granular quartz with hematite	Michigamme Mine.
(6a)		Mine dumps, Barron Mine, Humboldt.
(7)	"Greenalite"	Maitland Pit, Palmer.
(8)	Oxidized "greenalite"	" " "
(9)	Various altered phases	Almost any mine dump and many of the old pits.

DESCRIPTION OF TYPES

(The numbers in parentheses correspond with the numbers in the table)

(1) Cherty Iron Carbonate.

Usually chert and siderite in bands less than 0.1^{mm} to over 2^{mm} in thickness. Both minerals may be the same color. Either of them may be light gray, dark gray or almost black. The siderite is often somewhat yellowish from oxidation. The siderite cleavage faces are generally too small to be seen with the hand lens and are usually lessthan 0.1^{mm} across unless there has been some recrystallization. Usually from 40 to 60% chert. Occasionally contains ankerite instead of siderite in some horizons and some thin layers of slate or other argillaceous material may be seen in some beds. Where partly recrystallized (1a) the carbonate may show cleavage faces up to several millimeters across where it has recrystallized around the broken layers of chert. Disseminated magnetite, with the octahedral faces any size up to about 1^{mm} may occur in varying small amounts. In any one bed the carbonate is usually recrystallized to nearly uniform size except where the bed is closely folded or faulted.

(2) The cherty iron carbonate rusts along exposed surfaces, cracks, joint planes and less rapidly along the bedding in some layers, with "limonite" or earth hematite developing, until eventually all of the carbonate is (3) oxidized. The chert may be stained yellowish, brownish or occasionally reddish.

(4) "Grünerite" Rocks.

"Grünerite" as used here is a general term including grünerite, cummingtonite and other amphiboles high in ferrous iron but usually low or lacking in alumina, common in the iron formation.

The "grünerite" may be almost microscopic in size or more commonly reach a length of 2 to 6^{mm} and frequently even longer. It is commonly developed nearly perpendicular to the bedding, extending across the boundary between the ferruginous and the siliceous layers. It is generally lacking in the thicker layers that were originally either nearly pure chert or pure siderite. The "grünerite" seldom occurs in rosettes in type (4), although rosettes are common in type (4a) and (4b) and predominant in type (4c). In type (4) it is commonly in partly radiated tufts roughly perpendicular to the bedding. Another common occurrent is in interlacing needles or fine prisms with their long directions parallel or nearly parallel to the bedding. This was often seen where the iron formation had been sheared nearly parallel to the bedding, but such shearing may not have been necessary to produce this effect. In type (4) the magnetite was disseminated in many instances, but more commonly occurred in rather well defined bands. It was found almost microscopically fine and compact in the beds in some places, and in other localities the magnetite was quite coarsely crystalline, occasionally showing octahedral faces several millimeters across.

The granular quartz may be loosely coherent and from very fine to more than 1^{mm} in diameter of grain. The iron formation may then resemble a highly ferruginous sandstone. On the other hand, the granular quartz may be much less "Sugary" in appearance and may even be strongly bound together in interlocking particles that it is easy to trim specimens across the bedding. This phase often resembles a ferruginous quartzite.

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

Garnetz, 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 graduations 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 mineral 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 3mm.

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 - Fe3O4. In octahedrons up to 6mm as well as coarse to microscopically fine.

Pyrolumite or other manganese oxide, altered from manganite.

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

Göthite and "limonite". Fe2O3. (NOH) Described above.

Calcite - CaCO3. 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 - KAlSi3O8.	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, Grünerite, 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 bedrons 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. Apparently the chief source of Phosphorus in the ore.
Barite - BaSo4.	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 - CaSo4.	In seams and cavities. No abundant but probably less rare than gypsum.
Gypsum - CaSo4. $2H_2O$.	In scales and plates disseminated through the ore and in seams and cavities. Also in broad plates sometimes found several inches across.
Melanterite - FeSO4. $7H_2O$.	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,Ba,Al.	Up to several inches to length. Usually less than 5^{mm} long. Some tabular parallel to b and others tubular 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 scale 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 acros 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 gentle 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 grünerite 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", magnetic 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 stated, 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 classic 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 Clarkburg 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 Nagaunee 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 sheer 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 $+ 2^{\circ}$), 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 intrusion 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 graywacke and slates that are usually mapped as Michigamme. The tuff thins out rapidly to the westward and is replaced by generally thick graywacke 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 Keweekawan, 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 predominently 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 any 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 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-terrestial, 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 megnetic 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 with-out 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 area 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

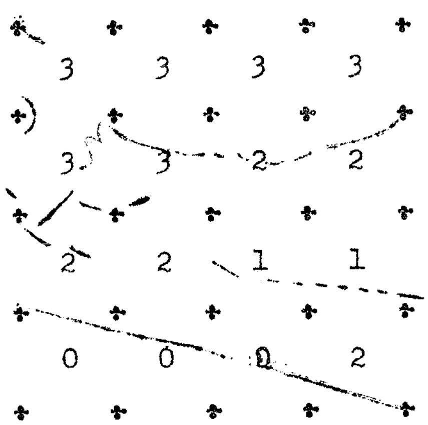
The following portions of the Lake Michigamme area are considered the more favorable for exploration. They are underlain by either the Negaunee or the Bijiki iron formation, or by both. No recommendations are being made separately for the Goodrich, as that horizon is not likely to be productive unless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



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 NW$\frac{1}{4}$ of the SE$\frac{1}{4}$, and another similar hole about 600 yards due east of there, near the east line of the NE$\frac{1}{4}$ of the SE$\frac{1}{4}$, 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 NW$\frac{1}{4}$ SE$\frac{1}{4}$ and into the south half of the NE$\frac{1}{4}$ would be advisable, and also whether exploration should be continued into the north half of the SW$\frac{1}{4}$ or the SE$\frac{1}{4}$ of the SE$\frac{1}{4}$ of the section, all of which forties are underlain by one or both iron formations.

Any exploration in the NW$\frac{1}{4}$ of the section should be deferred until information from the above drilling is obtained. The west half of the NW$\frac{1}{4}$ 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 S$\frac{1}{2}$ of the SW$\frac{1}{4}$ and part of the SW$\frac{1}{4}$ of the SE$\frac{1}{4}$ 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 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.

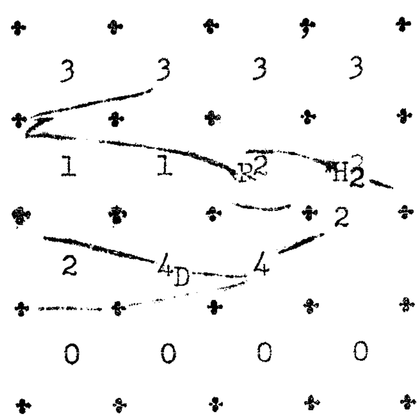
A magnetic belt, probably due to south dipping Negaunee iron formation, was crossed about 500 paces south of the northeast corner. What is probably the same belt was found a few paces south of the northwest corner and followed for a short distance, but not far enough to determine whether or not it continued 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^{o} to 12^{o} (adjusted values). No outcrops exist along this stretch of sweep 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 megnetic 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.



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.

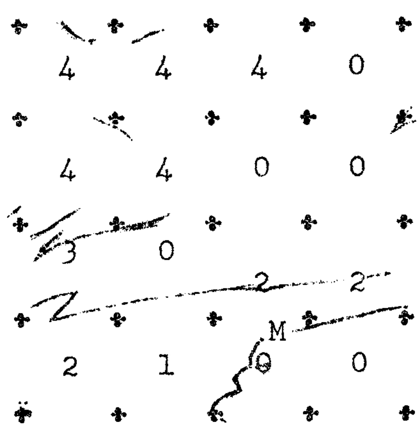
Between the Pascoe (SW¼ of the NE¼) and the Hortense (SE¼ of NE¼) there is seemingly some chance for additional, low grade ore. The dip needle readings indicate that iron formation underlies much of the southern half of the Hortense forty and the north part of the forty immediately to the south, but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

In the forty immediately east of the Dallibe (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)



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 = Marino 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 20 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$\frac{1}{4}$.

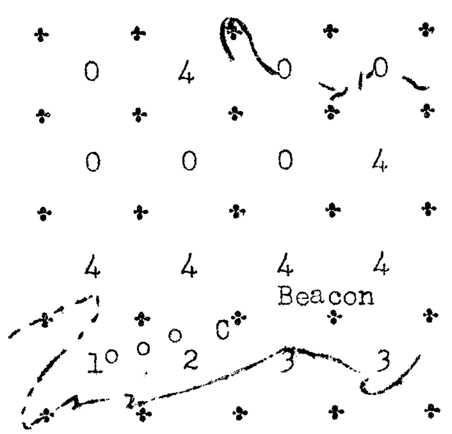
Southeast of the Marine, the southern limb of this trough swings to the southward past the south 1/4 post and is anticlinal in general structure with probably only small synclines with only a little lean ore likely to occur in them.

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 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.



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

C = Champion Cave-in.

ooo = 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.

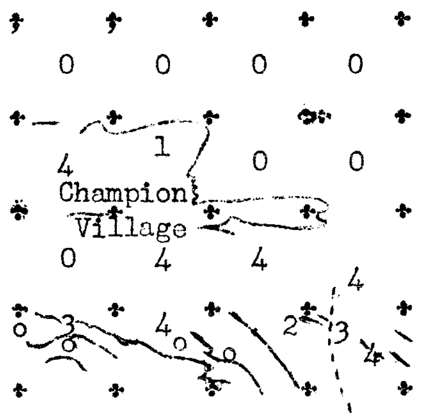
The NW¼ of the SW¼ is underlain by the Negaunee and Bijiki iron formations, both of which are probably mostly on the nose of a northeasterly plunging anticline.

The NE¼ of the SW¼ 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 SE¼ of the SW¼ 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 SW¼ of the SW¼ 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.

o o o = 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 NW¼ 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 SW¼ of the NW¼ 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 SE¼ of the NW¼ 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 NW¼ of the SW¼ 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 NW¼ of the SW¼ 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 SW¼ of the SW¼ 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 grünerític 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.

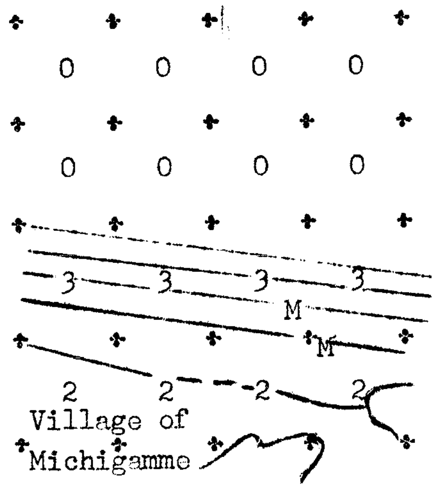
There is a westward pitching syncline of considerably crumpled grüneritic Bijiki lying along the north line of the NW¼ of the SE¼ but it is not likely to carry much ore except near the center of the section.

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.

M = Michigamme Mine

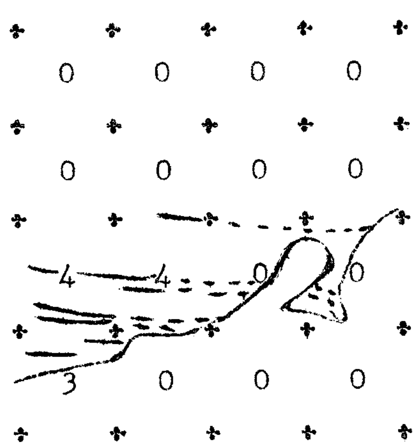
No part of the north half of this section is underlain by iron formations, other than a thin, non-productive zone at the base of the Negaunee.

The N½ of the SW¼ and the N½ of the SE¼ 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 N½ of the SE¼, 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 grüneritic 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.



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

4 = Possible ore at depth.

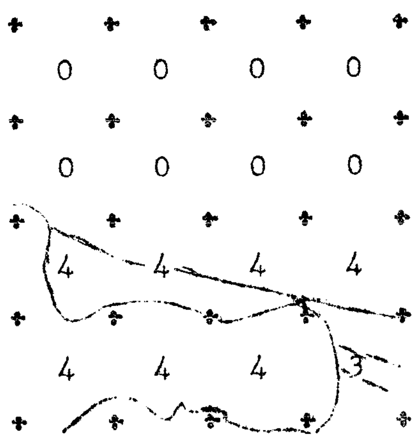
0 = Either no underlying iron formations (in the northern half)
or
0 = Underlain, at least in part, by iron formation but beneath Lake Michigamme.

There are no iron formations underlying the north half of this section. The N½ of the SW¼ 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 o

The SW¼ of the SW¼ 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.



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.

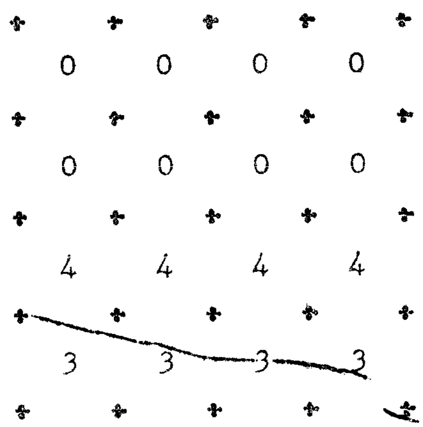
The N¼ of the SW¼ and the NW¼ of the SW¼ are underlain by the lower part of the Negaunee iron formation and by Clarksburg intrusives. There are no outcrops of iron formation or Goodrich, but from the magnetic survey, the structure is probably similar to that in the NW¼ of the SW¼ of Section 20, and these forties are not likely to carry any appreciable amount of ore.

The NW¼ of the SE¼ has a little of the bottom part of the Negaunee cutting somewhat diagonally across the extreme southwestern part. Probably no ore.

The SE¼ of the SE¼ is underlain by the top of the Negaunee, there being a very strongmagnetic 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 Ketchewn 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.



3 = Possible trough and ore.

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

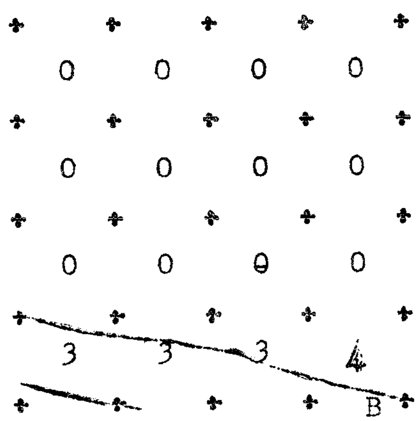
0 = No underlying iron formations.

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. RR., 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.



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.

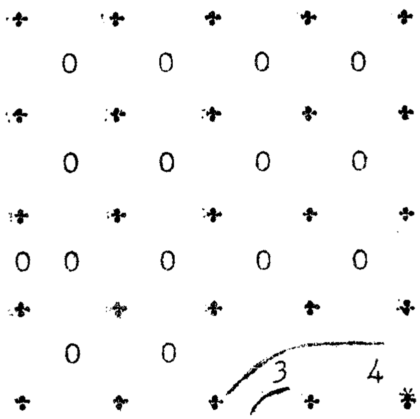
B = Location of dip check "B" at base camp.

There are no iron formations in the E$\frac{1}{4}$ 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.



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

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

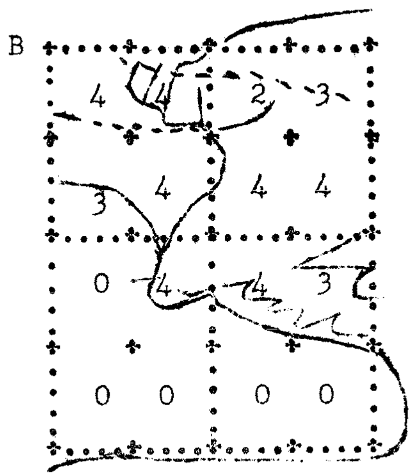
0 = No iron formations present.

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 S½ of the SE¼ 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.)



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 part 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 just 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.

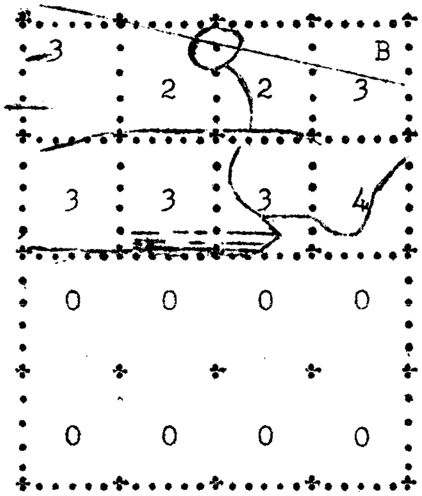
The NE$\frac{1}{4}$ of the SW$\frac{1}{4}$ contains outcrops of anticlinal grüneritic Bijiki striking and pitching about S 70° W. The only likely place for ore would be a deep under the mouth of the Peshekee River and the ore would probably be low grade.

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.48N., R 30 W.)



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.

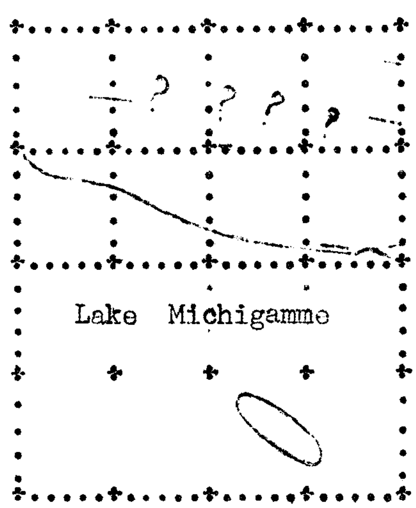
The geological mapping of this section was not completed despite the fact that the base camp was located on it near the northeast corner. The entire section was so handy to the camp that most of the mapping was deferred until such time as poor weather or other circumstances might render field work farther 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 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 gruneritic 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 synclines 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.)



The strong belt of Negaunee iron formation lies entirely north of this section, its closest approach being to within about 100 paces north of the northeast corner.

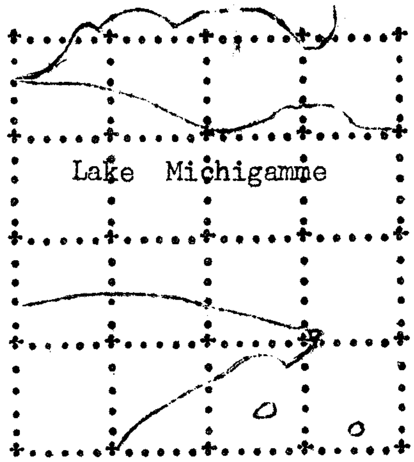
Only two dip needle traverses were run across the other iron belts in this section. The east line is crossed by a strong magnetic belt 110 paces south of the northeast corner, a weak belt about 350 paces south and another strong belt 550 paces south of the northeast corner. On the latter belt there was found outcrops of crumpled graphitic slate and Bijiki iron formation.

A strong belt was crossed at a point 500 paces east and 260 south of the northwest corner where nearly vertical graphitic slate was found in contact with grüneritic iron formation to the south. The dips were apparently 85° to the north but the dip needle readings indicate that the formations were overturned here. This belt strikes about east and west but does not line up with either of the strong magnetic belts that cross the east line of the section. No mapping was done in the area between, so the relationship of these belts is not known.

The only recommendation for exploration that can be made for this section at present is that the dip needle survey should be completed and the magnetic belts and outcrops should be located and accurately mapped.

A wooded island, several hundred paces long, in the SE$\frac{1}{4}$ of this section was not mapped, but it is probably underlain by the Michigamme formation.

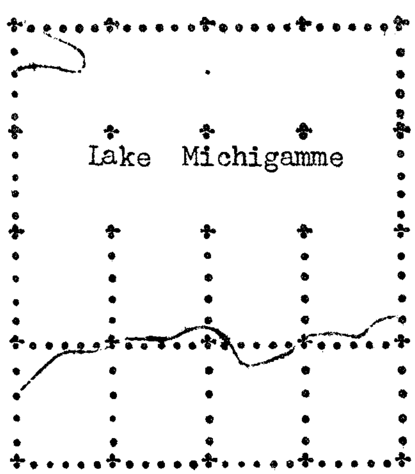
Section 28. (T. 48 N., R. 30 W.)



This section was not mapped in detail, but the three quarter mile long peninsula, running westward into Lake Michigamme, near the northwest corner is probably an anticline of Bijiki.

The half mile long peninsula, running eastward, in the south half of this section, and the islands in the SE$\frac{1}{4}$ of the SE$\frac{1}{4}$, are mostly Michigamme formation cut by east and west Superior pegmatites. The Michigamme formation consists here of mica schist, staurolitic schist and concretionary graywacke. The pegmatites are mostly feldspar-poor and some of them have a considerable amount of andalusite.

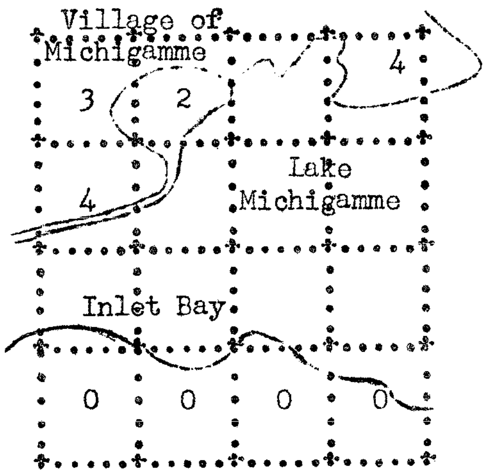
Section 29. (T. 48 N., R. 30 W.)



This section was not mapped but several outcrops were visited and examined near the south line, where Michigamme schist and concretionary graywacke were found in the south tier of forties on the south side of the lake. It is suspected that either an anticline or upthrust of Bijiki occurs near the south line.

The peninsula, jutting eastward into Lake Michigamme, in the NW$\frac{1}{4}$ of the NW$\frac{1}{4}$ is apparently an anticline of Bijiki, but no mapping was done there.

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



4 = Underlain by iron formation but structure not favorable for ore.

3 = Possibilities for ore.

2 = Possibly ore at moderate depth.

0 = Iron formation too deep and no indication of favorable structure for ore.

In the NW$\frac{1}{4}$ of the NW$\frac{1}{4}$ there may be a chance for ore in the Goodrich and Negaunee horizons if they are folded in the same manner as the overlying Bijiki which forms a crumpled syncline, pitching eastward into Lake Michigamme, in the NE$\frac{1}{4}$ of the NW$\frac{1}{4}$. There may be some low grade ore in the Bijiki horizon at moderate depth in this forty.

In the NE$\frac{1}{4}$ of the NE$\frac{1}{4}$ an anticline of Bijiki strikes eastward near the north line of the section. An east and west syncline of Bijiki probably underlies Lake Michigamme about the center of the

$NE\frac{1}{4}$ of this section.

The $NW\frac{1}{4}$ of the $NE\frac{1}{4}$ is mostly in a bay of the lake.

In the $SW\frac{1}{4}$ of the $NW\frac{1}{4}$ the grünerític Bijiki outcrops in a badly crumpled and faulted anticline that pitches eastward and disappears into the lake near the center of the $SE\frac{1}{4}$ of the $NW\frac{1}{4}$.

The $N\frac{1}{2}$ of the $SW\frac{1}{4}$ and the $N\frac{1}{2}$ of the $SE\frac{1}{4}$ are probably underlain by iron formations deep under the lake.

The south tier of the forties, on the south side of the Inlet Bay are almost entirely underlain by Michigamme schist and graywacke.

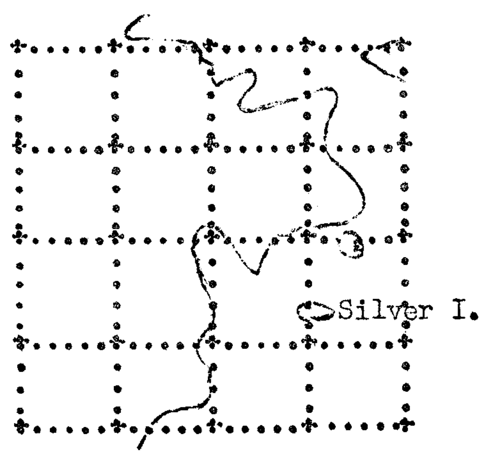
Section 31. (T. 48N., R. 30 W.)

No mapping was done in this section and the only outcrops examined were Michigamme schist and graywacke near the north line. Most of the section is probably similar, with the iron formations so deeply buried that they have little effect upon a dip needle. The Michigamme strikes east and west in a series of folds with the cleavage nearly vertical. This section is south of the west arm of Lake Michigamme.

Section 32. (T. 48 N., R. 30 W.)

The above description of Section 31 also applies to this section.

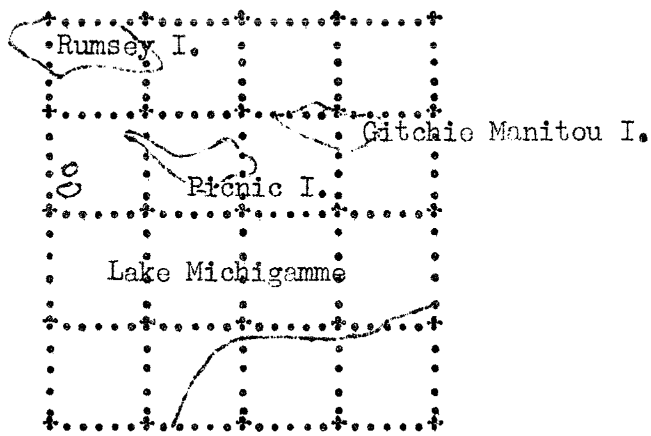
Section 33. (T. 48 N., R. 30 W.)



The mapping in this section was confined to that part of the west shore of Lake Michigamme that showed outcrops, and to all of the islands in the lake on this section.

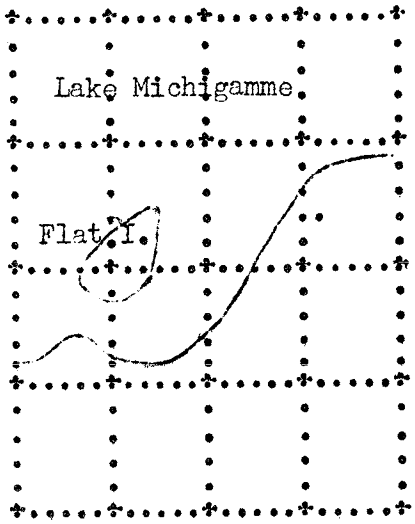
All of the outcrops are of the Michigamme and Clarksburg formations with east and west quartz veins and pegmatites. The Michigamme consists of east and west striking folds of concretionary and mica graywacke, mica and staurolitic mica schist. The Clarksburg appeared to be confined to a few beds of rather coarse tuff, none of them over a few feet in thickness. Several of the feldspar-poor pegmatites have an abundance of quite fresh appearing andalusite in crystals from one or two millimeters to several centimeters in diameter.

Section 34. (T. 48 N., R. 30 W.)



The only mapping done in this section was of the islands in the lake as shown in the accompanying small section map. The same formations were found as in Section 33 and with the same general strike and dip.

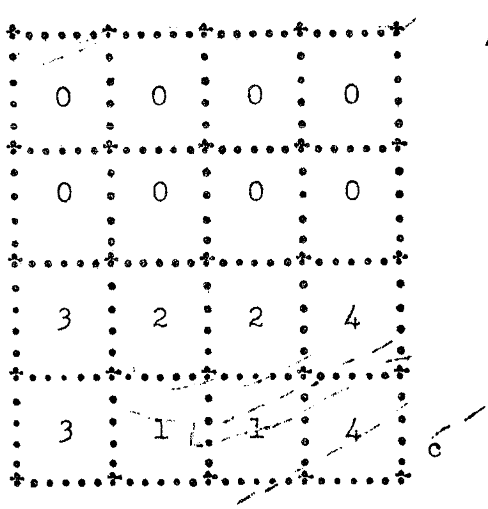
Section 35. (T. 48 N., R. 30 W.)



The only mapping done in this section was in the SE$\frac{1}{4}$ of the SE$\frac{1}{4}$ close to the south line. The outcrops were granitized Ajibik with numerous Superior pegmatites, all striking in general about S 60° W and dipping steeply northwestward. The shore of Lake Michigamme and Flat Island were examined but not mapped as the only outcrops found were of Michigamme or Clarksburg. No outcrops were found on Flat Island.

Magnetic work should be done in this section as the iron formations were mapped into the SW$\frac{1}{4}$ of the SW$\frac{1}{4}$ of Section 36 immediately to the east.

Section 36. (T. 48 N., R. 30 W.)



4 = Underlain by iron formations but structure not favorable for ore.

3 = Underlain by iron formations but not mapped and structure unknown but not likely to be favorable.

2 = Underlain by iron formations but ore either low grade or at great depth.

1 = Underlain by iron formations and structure favorable for ore.

c = #7 Shaft, Champion Mine.

From the Champion Mine workings, in the SW$\frac{1}{4}$ of the SW$\frac{1}{4}$ of Section 31 (T. 48 N., R. 29 W.), a wide magnetic belt continues about S 60° W to near the township corner. It then turns (probably both folded and faulted) to the northwestward, then bends back westward and enters this section, with a strike of about S 70° W, about 500 paces north of the southeast (township) corner. The belt then runs along the south tier of forties in this section, gradually curving more westerly, and near the south 1/4 post is striking east and west with the base of the belt very close to the 1/4 post. Just west of the north and south center line the belt appears to jog to the northward and then continues to the westward across the SE$\frac{1}{4}$ of the SW$\frac{1}{4}$ with a strike a little north of west.

The magnetic crest of this belt is about 200 paces north of its base and at the Champion Mine is about 100 feet in the hanging of the Goodrich contact. This leaves a width of from 400 to 450 feet for the Negaunee iron formation and as the dip is generally quite steep to the north, the probable width of the Negaunee is between 350 and 400 feet which seems to be about normal.

Clarksburg tuff and graywacke outcrop 300 paces north of the south 1/4 post or about 100 paces north of the crest of the magnetic belt. The Clarksburg strikes S 70° W and dips 75° northward. There are indications of a fault striking about S 65° W, and probably dipping northward, along the south edge of the ridge of Clarksburg. Whether such a fault is present or not, there would appear to be a possibility for ore, probably pitching northeasterly, in the Negaunee iron formation about 200 paces north of the south line in the SE$\frac{1}{4}$ of the SW$\frac{1}{4}$ and in the SW$\frac{1}{4}$ of the SE$\frac{1}{4}$. There may also be ore in the base of the Goodrich.

A grünerite-magnetite phase of the Bijiki iron formation outcrops at frequent intervals for severl hundred paces along another strong magnetic belt that is 200 paces north of and about parallel to the broad foot belt. This belt is widest and strongest near the north and south center line of the section but fades out a few hundred paces on either side of it. It is probably due to an upthrust or anticline of the Bijiki. The Clarksburg graywacke and tuff outcrop again, dipping northward, in the proper position parallel to and just north of this belt.

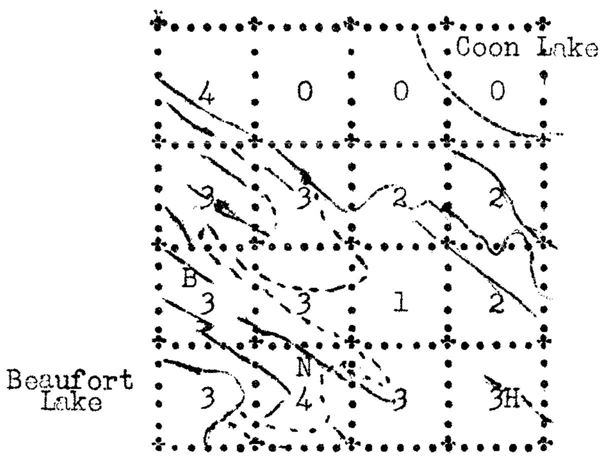
Time did not permit the completion of the dip needle survey in this section and the only work done in the SW$\frac{1}{4}$ of the SW$\frac{1}{4}$ was the running of the east and south boundaries. The dip needle readings along the south line of this forty continued low with a slight rise near the southwest corner indicating that, although the iron formation had not crossed the south line, it might be swinging a little closer to it. Numerous outcrops of granitized Ajibik, cut by pegmatites, all striking in general somewhat south of west and dipping northward, also indicated that the iron formation was still north of the line.

There is a row of old test pits, across the lower part of the Negaunee iron formation, near the north and south center line and a few pits along other north and south forty lines but no conclusive evidence was found that many of them reached ledge. Numerous pits, many of which reached ledge but got no ore, were also found across and along the belt of Bijiki that lies from 400 to 500 paces north of the south line. Any ore in this Bijiki horizon would more likely be found by drilling north of the Bijiki belt with the holes slanted to the south. The ore would probably be lean and the tonnage small.

In the north half of Section 36 no magnetic belts were found and the iron formations, if present, are presumably very deeply buried. The only outcrops found were of Michigamme and Clarksburg formations.

The $W\frac{1}{2}$ of the $SW\frac{1}{4}$ of this section and the $S\frac{1}{2}$ of Section 35 to the west should be thoroughly mapped. It seems likely that the iron formations may cross the south line of Section 35 near, or beyond, the south 1/4 post and either continue southwesterly across the $NE\frac{1}{4}$ of Section 2 (T. 47 N., R. 30 W.) or recross the township line forming still another trough before swinging southward to connect with the iron formation on the northeast side of the Republic trough.

Section 22. (T. 48 N., R. 31 W.)



B = Beaufort forty and Mine
N = Norwood Mine
H = Ohio Mine

0 = Not underlain by iron formations.

4 = Underlain, at least in part, by iron formation but structure not favorable for ore.

3 = May contain lean ore near surface or good ore at considerable depth

2 = Probably some good ore in Negaunee horizon and lean ore in Bijiki or ore in base of Goodrich.

1 = Probably considerable good ore in the Negaunee horizon. Probably lean ore in the Bijiki and some ore in Goodrich.

In the $NE\frac{1}{4}$ of the $NE\frac{1}{4}$ there is no iron formation, Ajibik slate and graywacke outcropping along the south shore of Coon Lake which covers most of this forty.

There is no iron formation in the $NW\frac{1}{4}$ of the $NE\frac{1}{4}$ which is underlain by Ajibik and by Clarksburg intrusives.

The $N\frac{1}{2}$ of the $NW\frac{1}{4}$ is mostly occupied by part of a large Clarksburg intrusion that extends across much of the northern part of this section. There is some buried iron formation, indicated by an outcrop of taconitic material and by two or three discontinuous magnetic belts, south of the river, in the $NW\frac{1}{4}$ of the $NW\frac{1}{4}$.

The $SE\frac{1}{4}$ of the $NE\frac{1}{4}$ has southwest dipping Negaunee iron formation striking diagonally across its southwestern part and a coarse Clarksburg intrusion, cut by an east and west Sibley dike, in the northeastern half. Only a little concentration was seen in the outcrop where the iron formation is cut by the vertical Sibley dike, forming a westward pitching trough on the north side of the dike, but there may be ore deeper down in this trough, especially to the westward.

South of this Sibley dike the iron formation dips toward the river, presumably flattening out in depth from the surface dips of from 45° to 60°. Another magnetic belt, probably due to the Bijiki formation, strikes southeasterly across near the southwest corner of this forty and lies about 300 paces above and parallel to the base of the Negaunee. This would indicate a width of about 800 feet for the combined Negaunee and Goodrich or a thickness, from the observed dip of the Negaunee, of about 600 feet without any allowance for folds, faults or hidden intrusives. The Negaunee probably accounts for between 300 to 500 feet of this thickness.

The outcrops of the Negaunee show a progressive change in strike from N 70° W near the west line to about N 45° W near the center of the forty. This curving of the formation indicates a trough pitching southwestward under the river. Such a trough, probably cut by other dikes not seen in the outcrops, may contain ore in the Negaunee horizon as well as some additional ore in the base of the Goodrich.

In the SW$\frac{1}{4}$ of the NE$\frac{1}{4}$, the conditions are similar to those in the forty just discussed except that the entire forty is underlain by the Negaunee iron formation, the large Clarksburg dike passing almost entirely north of this forty.

The S$\frac{1}{2}$ of the NW$\frac{1}{4}$ is underlain by iron formations as evidenced by several strong but somewhat discontinuous magnetic belts that appear to represent two narrow synclines of Bijiki that are separated by a broader anticline. There may be a moderate amount of low grade ore in the synclines. The Negaunee is less likely to be as closely folded and there may be ore in the Negaunee horizon but it is apt to lie at such a depth that exploratory work for it in these forties might better await developments on the adjacent forties to the east and southeast.

The NW$\frac{1}{4}$ of the SW$\frac{1}{4}$ includes the Beaufort Mine, in the Bijiki horizon, which is probably pretty well worked out except perhaps at greater depth. There is a fairly strong magnetic belt, somewhat interrupted, along the north side of the Beaufort pits. The formation is dipping steeply southward. There is another interrupted belt just south of the pits. This belt may be due to northward dipping Bijiki on the south limb of the trough but the dip needle readings suggest that this belt is also dipping southward and may be a repetition or upthrust of the northern belt, in which case there may be more Bijiki ore to the south of it and also under the east end of Lake Beaufort on the forty immediately to the south.

The SW$\frac{1}{4}$ of the SW$\frac{1}{4}$ is mostly under the east end of Lake Beaufort and may be underlain by ore in the Bijiki horizon. The underlying Negaunee may also carry ore but is probably at a considerable depth.

The NE$\frac{1}{4}$ of the SW$\frac{1}{4}$ is presumably largely anticlinal and unfavorable for ore except perhaps for a small, narrow trough of Bijiki near the center.

The SE$\frac{1}{4}$ of the SW$\frac{1}{4}$ carries an extension, worked by the Norwood Mine, of the ore body at the Beaufort. Only one small open pit, less than 500 feet long, and a few shallow test pits or shafts were found on this forty, and the ore appears to have been low grade.

The SE$\frac{1}{4}$ of this section is mostly under part of the large swamp that extends southward from the river, and very little of this area could be run because of the high water.

The NW$\frac{1}{4}$ of the SE$\frac{1}{4}$ is underlain by the iron formations and may contain ore in the Negaunee horizon at moderate depth in addition to possibilities of a little high grade ore at the base of the Goodrich and some lean ore in the Bijiki horizon.

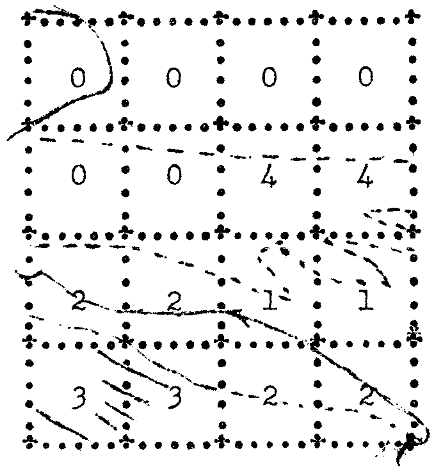
The NE$\frac{1}{4}$ of the SE$\frac{1}{4}$ is underlain by both iron formations and seems to have possibilities for ore in its western part but the magnetic belts swing more to the eastward near the east line of the forty which suggests the beginning of an anticlinal structure, although it is likely that crumpling and probable dikes may result in structural conditions favorable to the formation of some smaller ore bodies.

The SE$\frac{1}{4}$ of the SE$\frac{1}{4}$ includes the workings of the Ohio Mine in the Bijiki horizon. The magnetic belt passing near some of the old shafts and just north of the cave-in does not line up with the belt extending east-southeast from the Norwood. Due to the high water level in the intervening swamp this magnetic belt could not be followed between the Norwood and the Ohio but it appears that the north side of the trough is displaced by a sharp fold or northwesterly striking fault. If so, it would seem that the best place to look for additional ore would be about the middle of the west line of this forty or in the southwest part of it.

The SW¼ of the SE¼ carries an extension of the magnetic belt that is just north of andin the foot of the Norwood pit. This belt, which could not be followed east of the center of this forty because of high water in the big swamp, strikes about 150 paces south of what is presumably the same belt that lies just north of the Ohio Mine cave-in. The topography suggests a fault striking about S 55° east passing through near the northwest corner of this forty. The ridge extending for several hundred feet eastward into the big swamp from a point just south of the northwest corner of the forty may be due to an upthrust on the south side of this probable fault and had probably best be avoided in drilling.

Ore might be found in steeply northward slanted drill holes located about 400 paces north and from 700 to 800 paces west of the southeast corner, or on the south side of the ridge, in similar holes located about 300 paces north and between 900 and 1,000 paces west. The Bijiki horizon may carry lean ore and the underlying Negaunee, which is likely to be encountered in 2,000 feet or less, may carry ore.

Section 23. (T. 48 N., R. 31 W.)



0 = Not underlain by iron formation

4 = Only a little of the lower part of the Negaunee iron formation in narrow belts.

3 - Underlain by iron formations but ore bodies small and lean, or else good ore at considerable depth.

2 = Probable ore at less than 3,000 feet. Some lean ore at less depth.

1 = Probable ore at less than 1,000 feet. Some lean ore at less depth.

The N½ of this section contains no iron formation except for a few narrow belts of the lower part of the Negaunee caught up between forks of the large east and west Clarksburg intrusion. In the SE¼ of the NE¼ there are two or more such narrow troughs that may be large enough to contain a workable ore body, but this forty is not promising.

The N½ of the SW¼ is underlain by Negaunee iron formation with the southern part of these forties also underlain by the Goodrich and the Bijiki. The dip is steep southward at surface but anticlines of Bijiki in the forties to the south of here indicate that the Negaunee may also reverse its dip near the south line of these forties, thus forming a trough in which ore might occur. Even if the Negaunee does not come up again as the Bijiki does, it is likely that it will flatten out considerably and, as there is a strong probability that it will be cut by stringers of the large east and west Clarksburg dike just to the north, there is seemingly a fair chance for ore at workable depths.

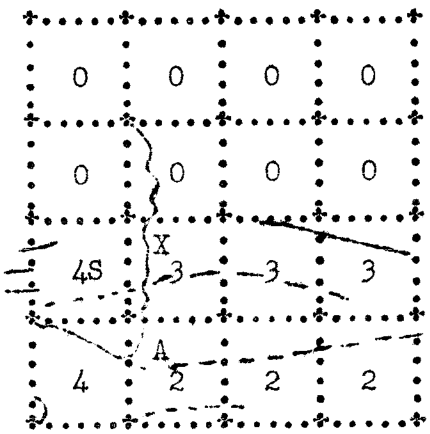
The N½ of the SE¼ appears to have a chance for ore as the conditions are similar to those in the forties to the west, and in addition there seems to be an appreciable curvature to the strike of the Negaunee suggesting a trough or troughs pitching southward under the river. The Goodrich quartzite close about the Negaunee iron formation outcrops about 400 paces west and 200 south of the center of the section and dips less than 30° to the southward which is about the lowest dip seen along the north limb anywhere in the Lake Michigamme area. This relatively low dip, coupled with the comparatively slow drop in the dip needle readings in going southward from outcrops of the Negaunee may indicate that ore bodies in this iron formation may be found closer to surface in these forties over a greater acreage than is usual for this area.

The SW$\frac{1}{4}$ of the SW$\frac{1}{4}$ is underlain by crumpled Bijiki iron formation quite close to surface. Except near the southwest corner of this forty, the Bijiki appears to be folded into a series of small, narrow synclines with wider anticlines between and the best chance for ore in this horizon is probably just south of the magnetic belt in the southwest corner. This belt is due to south dipping Bijiki and lies close in the footwall of the Ohio Mine workings to the west and the Portland pit tothe south. This forty is also probably underlain by the Negaunee iron formation but its structure is not yet known though it may not be as closely folded as the overlying Bijiki. It is probably not too deep to be mined if ore bodies are located in it though search for ore in the Negaunee horizon on this forty had perhaps best be deferred until the forties to the north are tested.

The SE$\frac{1}{4}$ of the SW$\frac{1}{4}$ is probably mostly anticlinal with only small narrow troughs of Bijiki. This forty may also contain ore in the underlying Goodrich and Negaunee horizons but exploration for it might await developments on the forties to the north.

The $S\frac{1}{2}$ of the $SE\frac{1}{4}$ is underlain at no great depth by the Bijiki, a great deal of which is probably anticlinal in structure and not very promising. Deeper down there may be ore in the Negaunee horizon but tests should await the exploration of the forties to the north or to the east in Section 24.

Section 24. (T. 48 N., R. 31 W.)



0 - Little or no iron formation and no ore.

4 = A little ore near surface and a moderate amount at depth.

3 = A little ore near surface with a chance for considerable ore at depth.

2 = Probably good ore at depth.

S = Spurr Mine. A = Anderson Saw Mill

X = Small open pits.

A large Clarksburg intrusion strikes about east and west through the middle of this section. North of this intrusion there appears to be only a little of the lower part of the Negaunee iron formation, with some narrow belts also caught up or included in, or between forks of, the Clarksburg. It does not seem likely that any profitable ore body will be found in the north half of this section.

In the next tier of forties to the south, branch dikes or sills of Clarksburg alternate with belts of the upper part of the Negaunee, with the Goodrich and Bijiki lying mostly to the south of the Clarksburg. There are probabilities of small ore bodies lying against or between some of the Clarksburg dikes and along the Goodrich contact.

In the $NW\frac{1}{4}$ of the $SW\frac{1}{4}$ a narrow ore body, in a magnetite-granular quartz phase of the Negaunee, was mined at the Spurr. The workings were along the south edge of a Clarksburg dike or sill and do not appear to have gone very deep. As there are dip needle indications of an anticline or upthrust to the south of this forty, it is probable that the iron formation forms a trough or at least flattens considerably at moderate depth and that more ore might be found by carrying the Spurr Mine workings deeper.

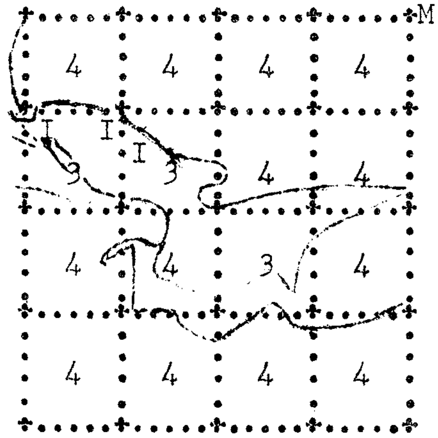
In the $NE\frac{1}{4}$ of the $SW\frac{1}{4}$ the iron formation strikes nearly east and west and the Clarksburg intrusive seems somewhat thinner. A small open pit near the center of this forty was apparently in ore though quite thin. The conditions for encountering more ore at depth seem better in this forty than in the forty to the west.

In the $N\frac{1}{2}$ of the $SE\frac{1}{4}$ the conditions also seem favorable for ore, especially at depth and at or near the Goodrich contact.

The $SW\frac{1}{4}$ of the $SW\frac{1}{4}$ has some apparent possibilities for a little ore in its northeastern part under the swamp south of the railroad. The northwest part of this forty is probably partly over an anticline.

The $SE\frac{1}{4}$ of the $SW\frac{1}{4}$ and the $S\frac{1}{2}$ of the $SE\frac{1}{4}$ seem to offer good possibilities of ore in a moderately deep trough near the north line of these forties, and what is probably an anticline or upthrust of iron formation seems to cross the southern part. The dip needle readings suggest that both limbs of this anticline, if such it is, will probably be found dipping south.

Section 25. (T. 48 N., R.31 W.)



4 = Underlain by iron formations but structure not favorable for ore in large amount except at considerable depth.

3 = Some ore near surface with **fair** chance for considerable ore at greater depth.

I = Imperial Mine workings.

M = Michigamme Village.

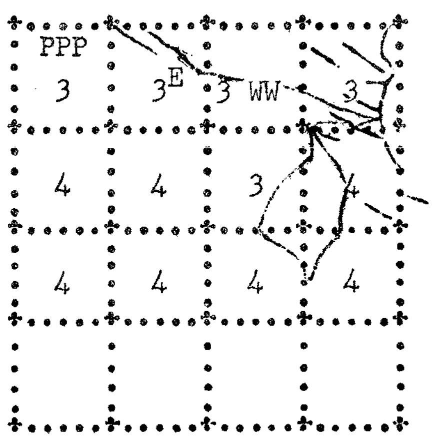
The NE. In this quarter section on definite magnetic belts were found north of an anticline of grüneritic Bijiki that outcrops at intervals, near the north shore of an arm of Lake Michigamme, from 400 paces west to about 100 paces north of the east 1/4 post. The dip needle readings from the north line gradually decrease until near this anticline. While it is probable that there are folds and perhaps ore bearing troughs in these forties, the dip needle indications are that they are so deeply buried that the structure was not revealed by the magnetics.

In the N½ of the NW¼ the dip needle readings varied but little except for local rises of two or three degrees. No definite pattern to the slightly higher readings was noted and they may have been due to small, deeply buried folds or even boulders.

The S½ of the NW¼. The strong magnetic belt of grüneritic Bijiki that was followed and mapped along the northern edge of Lake Michigamme toward the center of this section, was lost at the edge of the swamp along the river. A strong belt, considered likely to be the same one, either faulted or folded sharply back, was picked up just north of the center and followed northeasterly a short distance where it curved through north to the west and was followed to a point about 500 paces north of the west 1/4 post where it was lost. This belt skirted the north side of the workings of the Imperial Mine, which are confined to a half mile long fold in the formation. It is probable that a south dipping thrust fault, striking about N 60° W and about parallel to the river, may form the southern limit of the Imperial ore body. There may be more ore in this Bijiki horizon under the river south of this probable fault. There may also be ore in the Negaunee horizon deep below the Bijiki in this part of the area.

The south half of this section is mostly a valley occupied by swamp, river and bayous, and may be underlain by ore although the only favorable indications are topographic as, going southward, the dip needle readings steadily diminish.

Section 26, (T. 48 N., R. 31 W.)



4 - Underlain by iron formations but structure not very favorable for ore except perhaps at considerable depth.

3 - Probable ore in Bijiki horizon near surface and possibility of ore in Bijiki and Negaunee horizons at depth.

E - East Portland Mine
P - Portland Mine.
W.- Webster Mine.

The NE¼ of the NE¼ is underlain by both iron formations and probably contains some narrow troughs of Bijiki ore as it is traversed by several magnetic belts, most of them rather short. The magnetic belt, from the Imperial Mine to the east, passes through near the southeast corner of this forty and the break in this belt near the east line together with the arrangement of short and apparently broken belts on this fort suggest a thrust fault striking about 70° W through the southeast corner. There might be ore in both the Bijiki ahd the Negaunee iron formations on the north side of such a fault.

The NW$\frac{1}{4}$ of the NE$\frac{1}{4}$ contains the pits of the Webster Mine and more ore in the Bijiki formation might be found at greater depth as the dip needle mapping indicates the probability of an anticline or upthrust close south of the Webster. Such an anticline might have both limbs dipping southward and ore might be found on the north side under such an overturned fold. Such a fold or fault might also be the start of another trough a short distance south of the Webster ore body.

The NE$\frac{1}{4}$ of the NW$\frac{1}{4}$ contains the pit of the East Portland Mine, and the east end of the large pit at the Portland, on the continuation of the Bijiki ore body from the Webster, and at the latter mine, there might be another ore body encountered to the south of the old workings as the dip needle mapping indicated the probability of an anticline or upthrust about 100 to 200 paces south of the east Portland pit.

The NW$\frac{1}{4}$ of the NW$\frac{1}{4}$ contains the Portland pit in which might be found additional ore at depth as well as in what may prove to be another trough to the south. The ore body at the Portland is a continuation of that at the East Portland and Webster, only minor faulting and undulations in the iron formation narrowing the ore body between.

The S$\frac{1}{2}$ of the NW$\frac{1}{4}$ showed steadily decreasing dip needle readings to the southward, but all readings were sufficiently high to indicate that these forties are underlain by iron formation. Although the magnetic work gave no indication of structure favorable for ore, except that the dip had probably become much flatter, a swamp across these forties might be taken as a favorable topographic indication.

The SW$\frac{1}{4}$ of the NE$\frac{1}{4}$ showed dip needle readings diminishing very gradually to the southward but high enough to indicate that there is iron formation at no very great depth. No favorable structure for ore was indicated by the magnetic work but most of this forty is occupied by a swamp and as the magnetic reading decreases so gradually it would indicate that the dip may have flattened a great deal and the possibility of ore beneath this swamp should be considered.

The SE$\frac{1}{4}$ of the NE$\frac{1}{4}$ is partly occupied by the main part of Bass Lake, to the east of which a few short indefinite magnetic belts were found. The land on the east side of Bass Lake is about 50 feet higher than the lake and swamp level and may be due to glacial till but this greater elevation may also be at least partly caused in the discussion of the forty to the north. The chances for ore in this forty are not considered promising.

The entire south half of this section shows steadily decreasing dip needle readings and the iron formations probably lie at too great a depth for effective exploration at present, although there is probably a broad, somewhat crumpled, deeply buried syncline from here southward in which there may be ore at a depth perhaps not too great for mining.

Section 27. (T. 48 N., R. 31 W.)

This section is underlain by the iron formations but except for the north tier of forties the dip needle readings indicate that it may lie at considerable, although not necessarily prohibitive depth. Exploration in this section should perhaps best start in the NE$\frac{1}{4}$ of the NE$\frac{1}{4}$ (south of the Ohio Mine) where there is a reasonable chance of locating ore at moderate depth, especially on one side or the other of a probable thrust fault that may be striking about N 60° W near the northeast corner of the section. This probable fault is shown on the small section map that accompanies the description of Section 22 to the north. Another probable parallel fault, also indicated on the same map, probably enters this section east of the magnetic belt near the north quarter post, and ore bodies might be found near it is the NW$\frac{1}{4}$ of the NE$\frac{1}{4}$ and perhaps in the forty to the west of there.

In the rest of the section the dip needle readings generally decrease steadily to the south and it is likely that the iron formations are quite deep. A small elliptical area of fairly high dip needle readings was found about 450 paces south and less than 100 paces west of the east quarter post and while they may have been due to a belt of iron formation coming near the surface, it is considered more likely that these high readings may be caused by a buried boulder of iron formation, several of which only partly buried and up to 1,000 tons weight, were observed in the sections to the east of there. No outcrops were found in this section.

Section 34. (T. 48 N., R. 31 W.), is apparently devoid of outcrops and the magnetic readings decreased steadily to the southward and in no part of the area gave any indication that the underlying iron formations were near enough to surface to warrant exploration at present.

Section 35. (T. 48 N., R. 31 W.)

The dip needle readings on this section become progressively lower to the south and southwest and no magnetic belts were found. The only readings that might have indicated proximity to an iron formation were found near the east quarter-post, about 500 paces west and 100 south of the northeast corner and near the center. In the first two instances a partially buried boulder, of grüneritic iron formation, and about 1,000 tons weight accounted for the anomoly. Near the center of the section the readings in a small oval were slightly higher than the surrounding readings and were probably due to a completely buried boulder. Many other similar areas would have undoubtedly been encountered had the magnetic surveying not avoided boulder strewn areas devoid of outcrops.

There are outcrops of east and west striking Michigamme schist in the SE$\frac{1}{4}$ of the SE$\frac{1}{4}$.

It is assumed that any productive iron bearing horizons are probably from several hundred to more than 2,000 feet deep over most of this section, and that drilling on this section is probably not warranted until section 26 to the north has been tested.

Section 36. (T. 48 N., R. 31 W.)

No magnetic belts were found on this section though irregularly scattered high dip needle readings near abnormally low (negative) ones were found in a boulder strewn area, of two or three acres extent, near the south quarter post. Considerable test pitting and trenching had been done there but the only pit that appeared to have reached ledge was sunk in the edge of what seemed to be a large angular boulder of magnetite interbedded with granular quartz. This appeared to be a fragment of the Negaunee iron formation and showed, both in the hand specimens and the outcrop, well developed polarity -- a condition that has frequently been observed in loose boulders of this material elsewhere in the district. This locality was described in Progress Report #11, "Geology of the Spruce River Area", 1944, Michigan Geological Survey.

Outcrops of east and west striking Michigamme formations were mapped near the northeast and the southwest corners of this section.

This section is probably largely underlain by the Bijiki and the Negaunee iron formations but at depths probably ranging from 1,000 to more than 2,000 feet and exploration is not considered advisable until work had been done in the south part of section 25 immediately to the north.

NOTE: The detailed description of a large number of specimens from this area has been omitted, but these descriptions can be obtained from the Michigan Geological Survey Office.