Open File Report LXIX

GEOLOGY OF THE LAKE MICHIGAMME AREA, BARAGA AND MARQUETTE COUNTIES

W. A. Seaman

1947

STATE OF MICHIGAN

DEPARTMENT OF CONSERVATION

GEOLOGICAL SURVEY DIVISION

GEOLOGY

of the

LAKE MICHIGAMME AREA

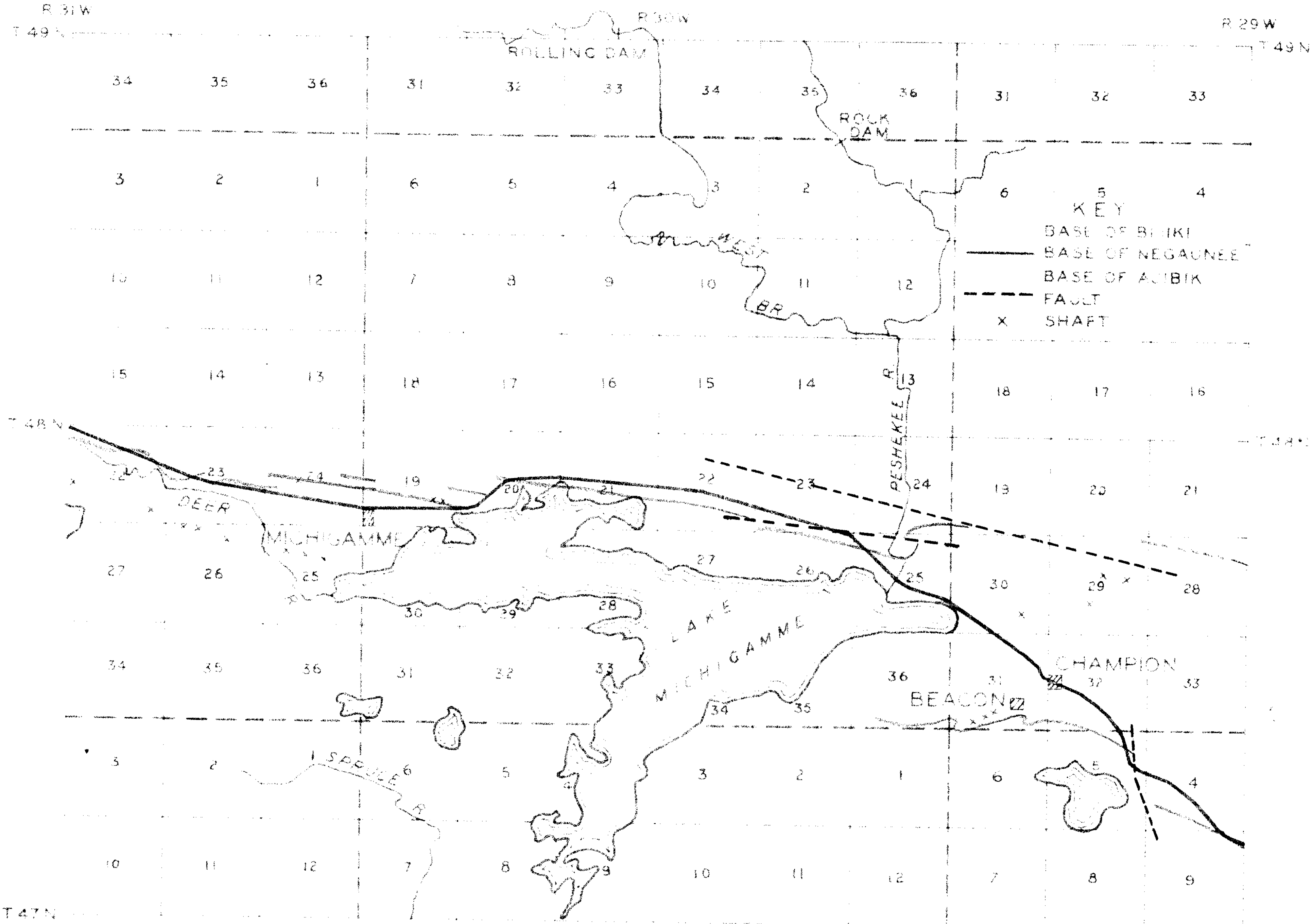
Baraga and Marquette Counties

By W. A. Seaman

Prepared in cooperation with
The Michigan College of Mining & Technology

1947

2nd Copy



KEY MAP—LAKE MICHIGAMME AREA

PLATE I

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 or the Michigan College of Mining and Technology.

C O N T E N T S

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 47 N., R. 29 W.	20" = 1 mile
4	Section 5, T 47 N., R. 29 W.	20" = 1 mile
5	NE$\frac{1}{4}$ 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	SW$\frac{1}{4}$ 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	SE$\frac{1}{4}$ Section 32, T. 48 N.,R 29 W.	40" = 1 mile
16	Section 33, T. 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	S$\frac{1}{2}$, T 48 N., R 30 W.	4" = 1 mile
19	SW$\frac{1}{4}$ T 48 N., R 30 W.	10" = 1 mile
20	SW$\frac{1}{4}$ 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, T 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	SE$\frac{1}{4}$ 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.30W.), 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°), 1:2 (26½+°) or some other fraction convenient for plotting.

The dial compasses used for most of the work were constructed for latitude 46½° which was the approximate latitude of most of the mapping. Other compasses at hand were for latitudes 47° to 49°, 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 se t 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 regulation, refraction, 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 118 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 leg and in many instances into still smaller ones. In addition, traverses were run to important geological points within the triangles 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 Gurley, 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 $\frac{1}{2}°$ obtained readings to the nearest $\frac{1}{4}°$ but it could usually be demonstrated that readings closer than $\frac{1}{2}°$ 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:- $7\frac{1}{4}°$ was recorded as 7+, 7-3/4° as 8-, and $7\frac{1}{2}°$ 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 other 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 $\frac{1}{2}°$ 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 or repaired 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. I, No. 1, 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 $4\frac{1}{2}$

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 specimen taken in each section. The specimens, 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 N., 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
Section 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 1	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

Location	Hand specimens mostly trimmed	Channel samples		Total
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 W.				
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	4
" 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

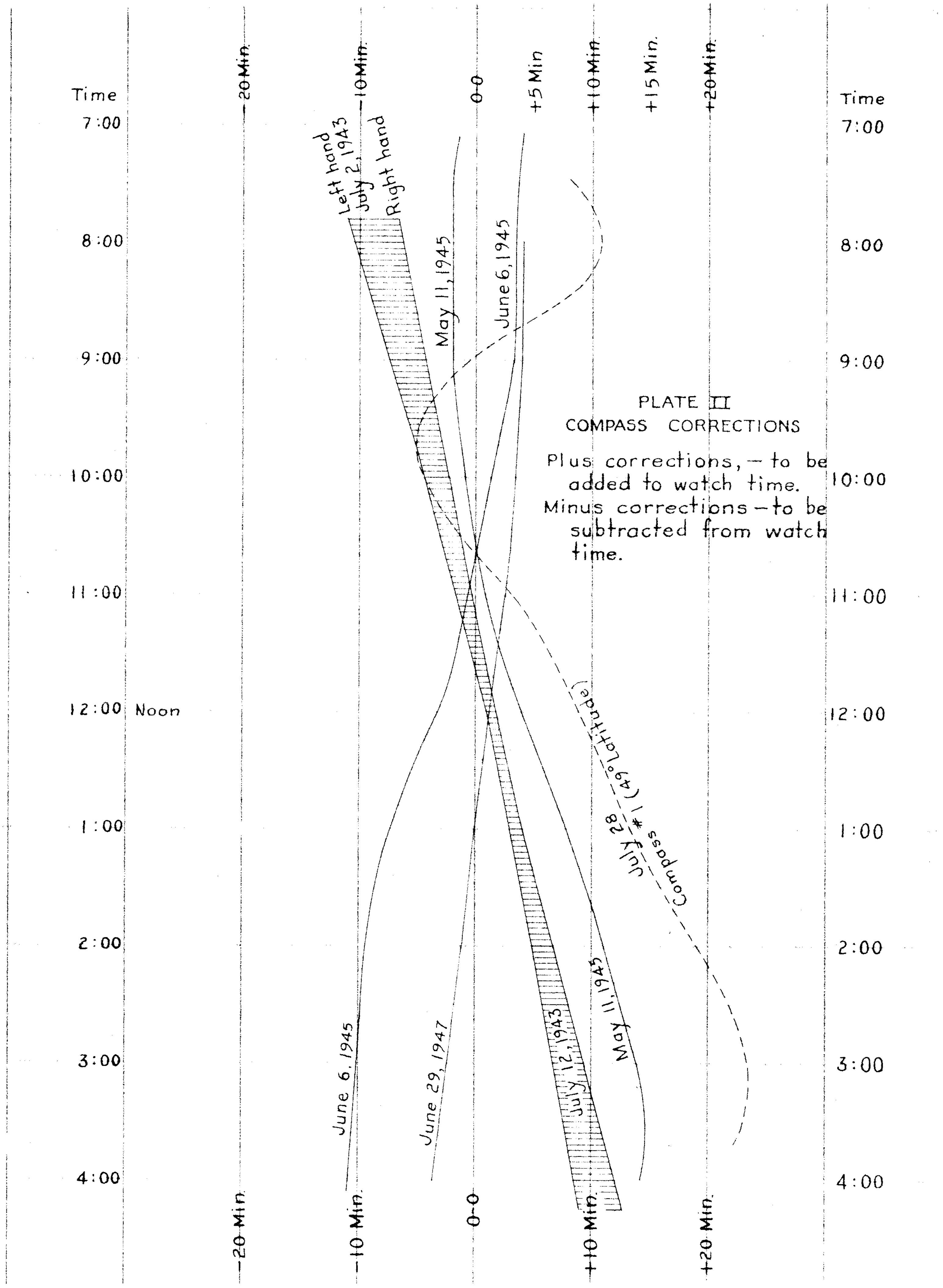


PLATE II
COMPASS CORRECTIONS
Plus corrections, — to be added to watch time.
Minus corrections — to be subtracted from watch time.
Time
7:00
8:00
9:00
10:00
11:00
12:00 Noon
1:00
2:00
3:00
4:00
-20 Min.
-10 Min.
0-0
+5 Min
+10 Min.
+15 Min.
+20 Min.
Left hand
July 2, 1943
Right hand
May 11, 1945
June 6, 1945
June 6, 1945
June 29, 1947
July 12, 1943
May 11, 1945
July 28 — Compass #1 (49° Latitude)

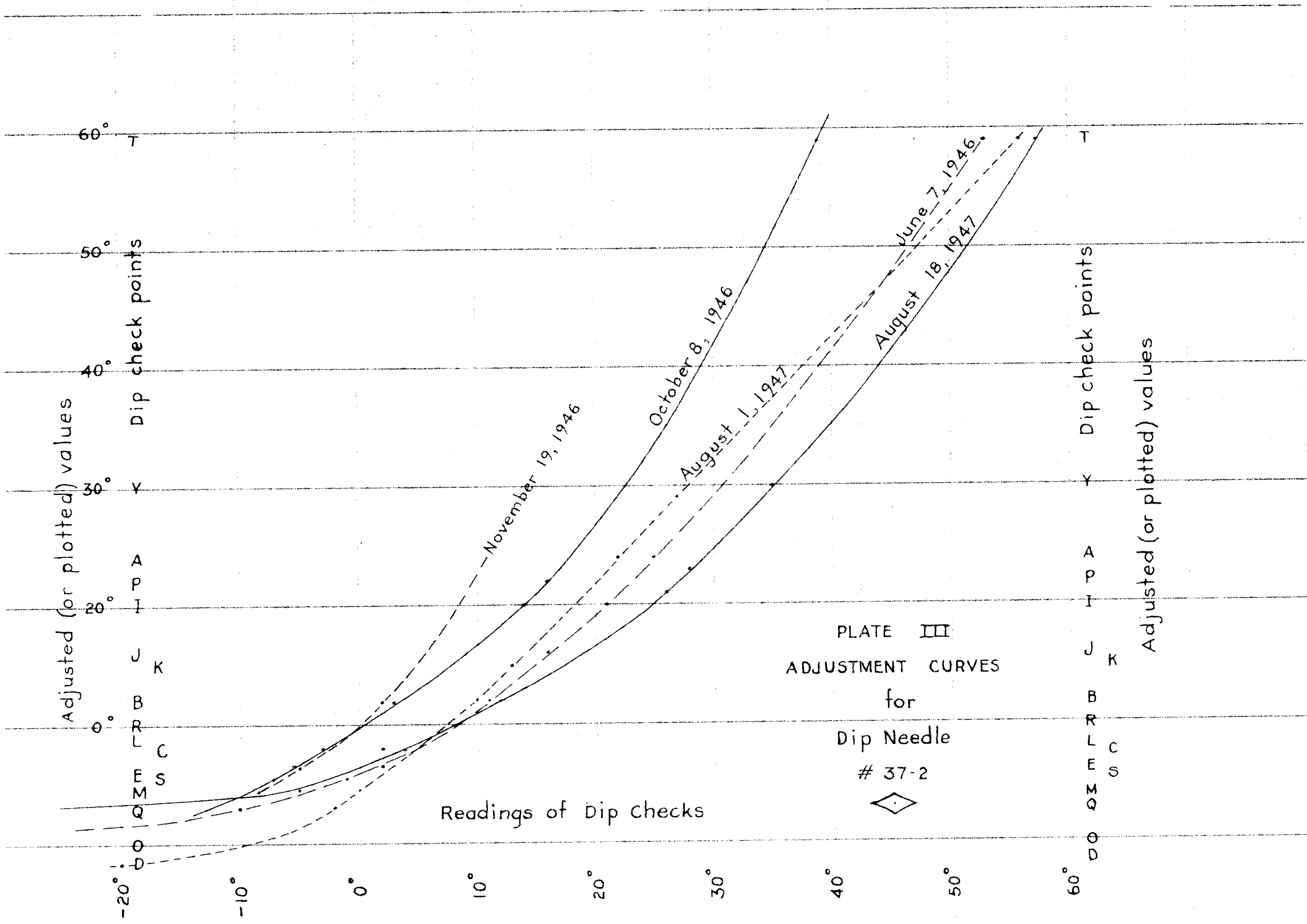


PLATE III
ADJUSTMENT CURVES
for
Dip Needle
37-2
Adjusted (or plotted) values
Dip check points
Readings of Dip Checks
November 19, 1946
October 8, 1946
August 1, 1947
June 7, 1946
August 18, 1947
60°
50°
40°
30°
20°
0°
-20°
-10°
0°
10°
20°
30°
40°
50°
60°
T
Y
A
P
I
J
K
B
R
L
C
E
S
M
Q
O
D

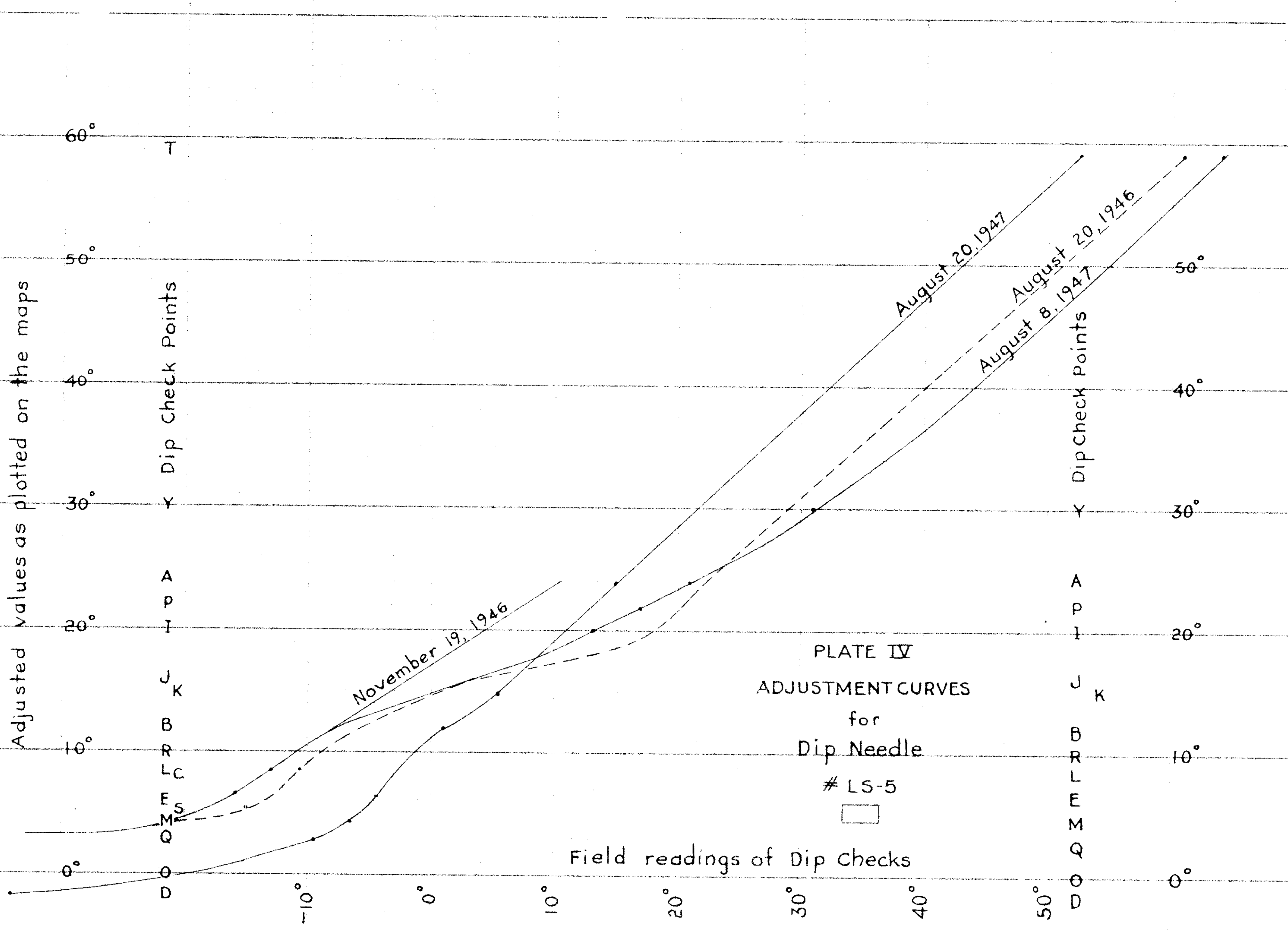


PLATE IV
ADJUSTMENT CURVES
for
Dip Needle
LS-5
Field readings of Dip Checks
Adjusted values as plotted on the maps
Dip Check Points
T
Y
A
P
I
J
K
B
R
L
C
E
S
M
Q
O
D
August 20, 1947
August 20, 1946
August 8, 1947
November 19, 1946
60°
50°
40°
30°
20°
10°
0°
-10°

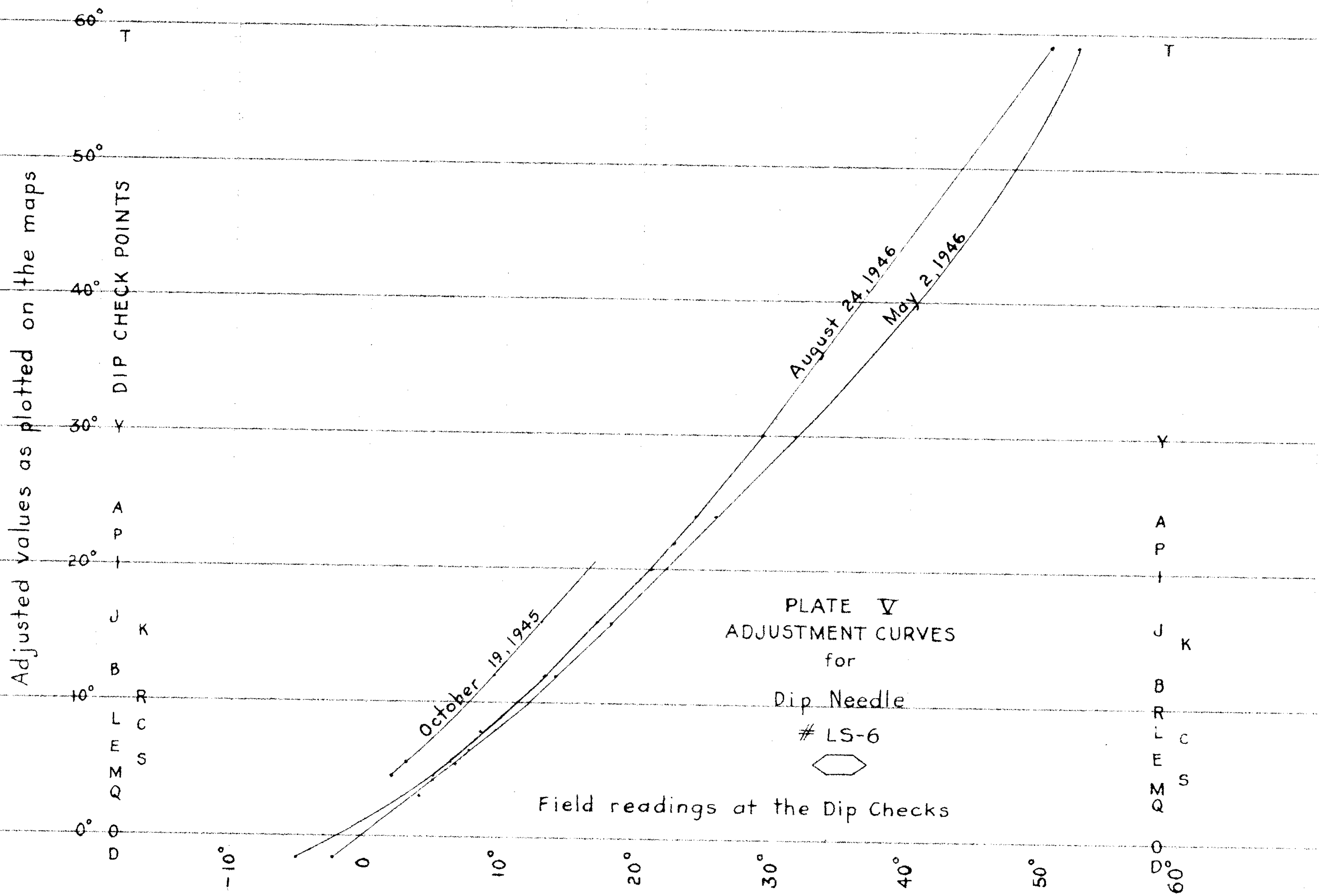


PLATE V
ADJUSTMENT CURVES
for
Dip Needle
LS-6

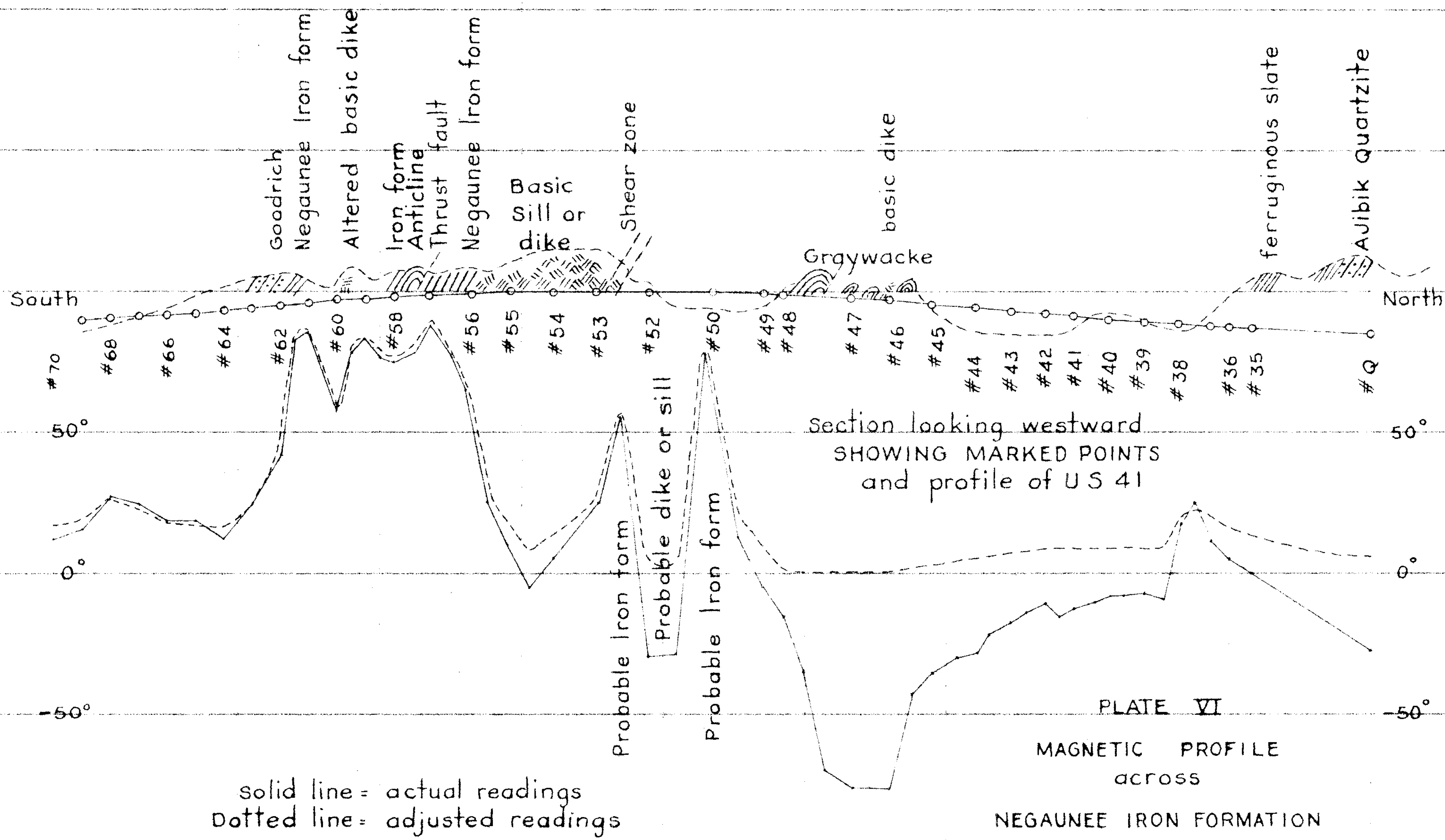
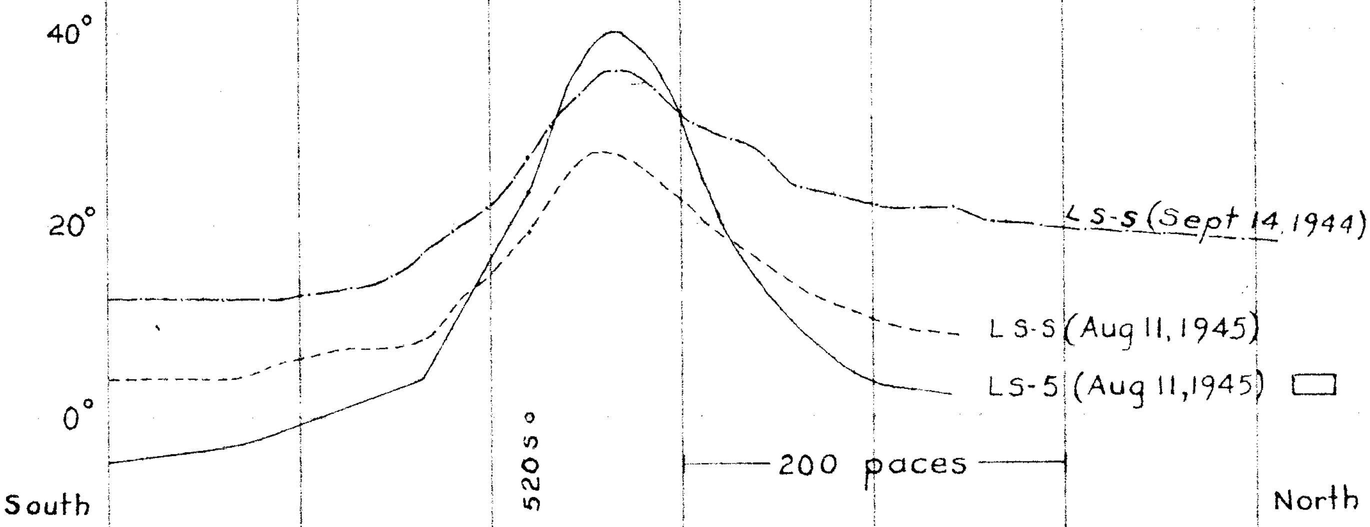


PLATE VI

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

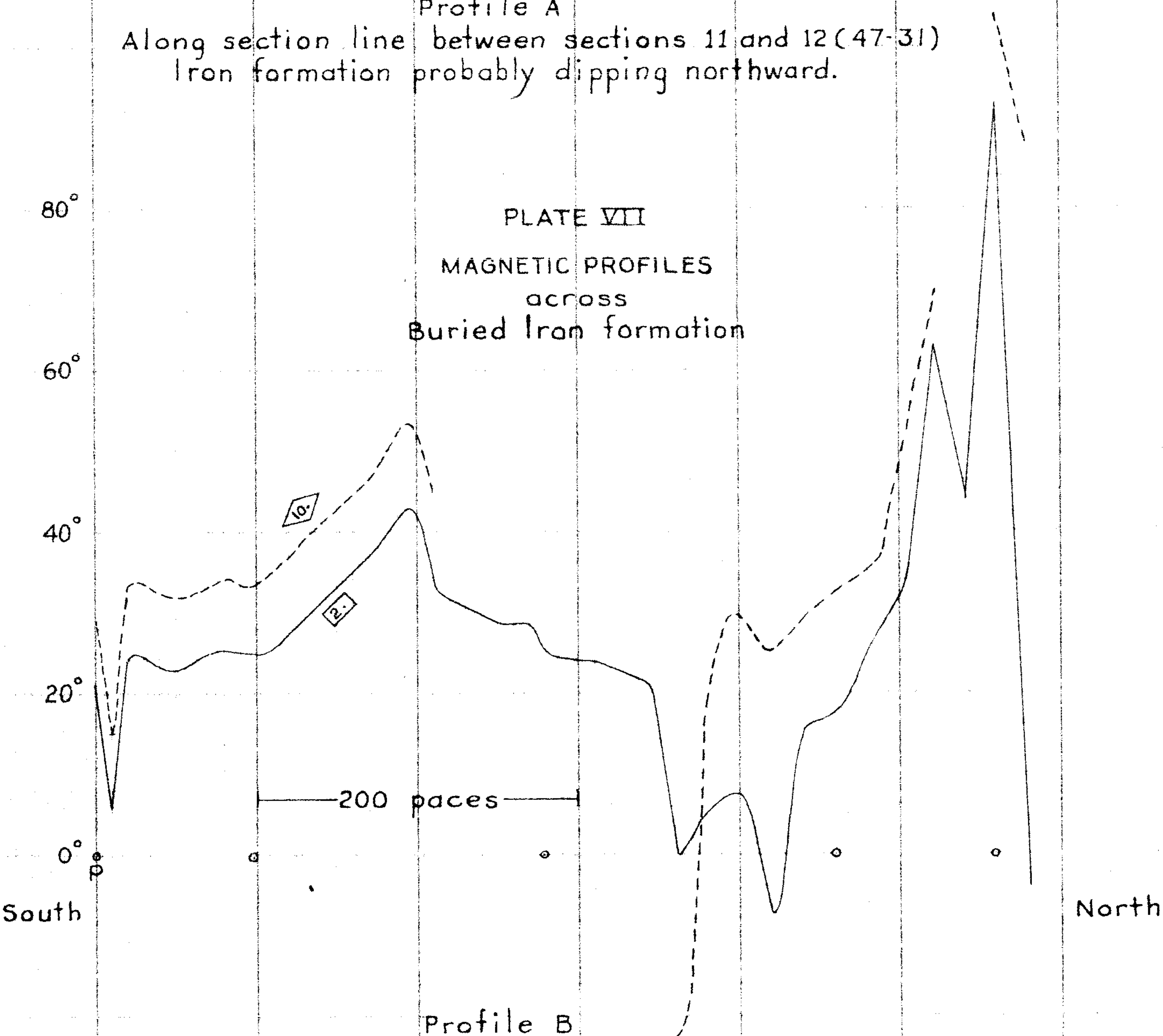
|—— 200 Paces ——|



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 4 ft 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.
P	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. Bijiki 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 syncline 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° 3	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.

TABLE 1 (Continued)

Marked Point	Assigned Value	Location
L	$8\frac{1}{2}°$	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°	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	$6\frac{1}{2}°$	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	$5\frac{1}{2}°$	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	$4\frac{1}{2}°$	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°	Sec. 21, (48-30). About 410 paces E, 90 N of position of $W\frac{1}{4}$ post which was not found (probably in Ketchewa 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° (0°	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	$-1\frac{1}{2}°$	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 Checks		Needle # 37-2				Needle # L S-5				Needle # 29-5			Needle # L S-6		Needle # 16		Needle # 46-1				
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.°
	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		

TABLE 3

Dip Checks	Actual reading with different needles: Highest	Weighted Average	Lowest	Differences: Maximum	Weighted Average	Minimum	Sensitivity of Different Needles: Maximum	Weighted Average	Minimum	Conversion Factor	Adjusted Readings: Late 1947	Early 1947 &Late 1946	Early 1946	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
		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	
		Champion	Granitization, pegmatites, folding, faulting.	
EOZOIC		Kona	Dolomite, slate, schist, gneiss	
EOZOIC		Mesnard	Quartzite, gneiss, slate, schist, etc.	
EOZOIC		Kitchi	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 actinolite 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 amphibole, 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 northeast 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 unconformably 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 consitute 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 Ajibik 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 quartzitic 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 predominantly 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 Kitchi, resulting in the north shore line of the later 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 axes 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 article 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 farther 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 Martins 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 traverse s across the iron formati on 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 affected 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 earthy hematite)

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

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

(3) ↓ (5) Jaspilite ↓ (6) Magnetite (± specular hematite & granular quartz

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(7) "Greenalite" → (8) Granular ferruginous chert or Granular siliceous "limonite" or earthy hematite

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

(8) ↓ (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 Lucky Star shaft, Negaunee. Chicago and 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. $1\frac{1}{2}$ 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.

Uusually 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 less than 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 earthy 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 so strongly bound together in interlocking particles that it is easy to trim specimens across the bedding. This phase often resembles a ferruginous quartzite.