Ishpeming, Michigan
November 5, 1952
IRON CO.
CLEVELAND, OHIO

Mr. C. W. Allen
General Manager
Building

Dear Sir:

I am handing you, herewith, two copies of the report of the Geological Department for the year ending December 31, 1951.

The activities of the Department expanded materially over those of previous years. This required a corresponding expansion in personnel which stands out quite prominently by comparing this report with that of 1950. In spite of this increase, however, we were unable to accomplish all of our objectives in accordance with the most desirable time schedule. The expansion, both in activities and personnel, has continued during the current year, much of it in areas outside of the Marquette Range.

The report, in my judgment, is quite complete and, since it incorporates the combined efforts of the geological "Family" group, I can add nothing of material importance at this time.

Very truly yours,

E. L. Derby, Jr.
Chief Geologist

EML: des encs.
REPORT OF GEOLOGICAL DEPARTMENT FOR YEAR
ENDING DECEMBER 31, 1951

The following is the report of the Geological Department for the year 1951:

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I. Staff
II. Geological Field Work
III. Geophysical Field Work
IV. Exploration Drilling Division
V. Surface Exploration
VI. Underground Exploration
VII. Land Offers and Outside Explorations
VIII. Other Departmental Highlights

This report has been prepared through the cooperative efforts of each of the staff members. The geologist in charge of each project prepared the summary of his assignment. The editorial board consisted of E. L. Derby, Jr., H. W. Rembold, J. L. Patrick, Mrs. Belle Bloch, Mrs. Esther Fandrem and Burton H. Boyum.

I. STAFF

A. Distribution

During the year 1951, Ishpeming continued to be the headquarters and base from which the Geological Department operated. The staff increased in keeping with the accelerated rate of Company exploration. Tables I, II and III show the distribution of staff members.
TABLE I

E. L. Derby, Jr., Chief Geologist
Burton H. Boyum, Ass't. Chief Geologist

EXPLORATION DRILLING DIVISION

H. Walter Rembold, Sup't.
Edwin Jacks, Foreman
Swante Merrila, Foreman
Carl Ostlund, Foreman (C)

GEOLeOISTS

Gerald J. Anderson (D)
Robert M. Becker
David M. Bennett (E)
Layton C. Binon (F)
Rolland L. Blake (G)
Gilbert A. Dawe (H)
Kenneth H. Johnson (I)
Joseph L. Patrick (J)
Eric J. Rex
Robert W. Riedel

CONSULTANTS

Prof. William A. Longacre, Geophysics
Dr. Melville W. Bartley, Geology, Canada (A)
Dr. James M. Neilson, Geology, Canada (B)

TECHNICIANS

George M. Olson
Robert W. Ryan
Bruce G. Cain (K)

DRAFTSMEN

Archie Minnear
Pat S. Johnson

FIELD ASSISTANTS, TEMPORARY

David M. Bennett, Geologist (E)
Malcolm Conrad,
William P. Cromwell, Notetkeeper
Fred Paulus, Geologist
Leslie Price,
Terence T. Quirke, Jr., Geologist

SECRETARIAL

Mrs. Belle Bloch, Office Secretary
Mrs. Esther Fandrem (L)
Donald M. Carlson (M)
Miss Jean Jensen (N)

(A) Feb. 1, 1951 - Engaged as part time Chief Consultant
(B) June 18, 1951 - Engaged as part time Consultant
(C) Aug. 1, 1951 - Became Foreman
(D) June 18, 1951 - Joined permanent staff
(E) June 18, 1951 - Joined temporary staff
(F) Sep't. 15, 1951 - Joined permanent staff
(G) Dec. 1, 1951 - Transferred to Mather Mine "B" Shaft as Operating Engineer
(H) Nov. 15, 1951 - Joined permanent staff
(I) Nov. 1, 1951 - Transferred to Mather Mine "A" Shaft as Operating Engineer
(J) June 25, 1951 - Joined permanent staff
(K) April 2, 1951 - Joined permanent staff
(L) April 11, 1951 - Joined permanent staff
(M) June 1, 1951 - Transferred from shared basis with Engineering Department to permanent staff
(N) Sept. 1, 1951 - Transferred from shared basis with Engineering Department to the Recording Division

(M) July 16, 1951 - Joined Company and shared with Engineering Department
B. Figure 1.

Figure 1 is the photograph of the 1951 staff of the Geological Department, including both permanent and temporary personnel. This photo shows, in addition to the Geological Department members, those members of our field crews who were employed as compassmen under the Engineering Department.

V. Man-hour Summary

During the year 1951, the Geological Department employed, for at least a portion of the year, 25 people on a permanent basis. In addition to the permanent staff, we had a total of 9 temporary employees. The latter includes our 3 consultants and 6 geologists or notekeepers employed for the summer. The permanent employees worked a total of 37,659 man-hours and the temporary employees worked a total of 4,520 man-hours. This makes a total of 3,1 staff members and a total of 42,179 man-hours.

TABLE II

<table>
<thead>
<tr>
<th>DISPOSITION OF HOURLY RATE PERSONNEL</th>
<th>GENERAL STOREHOUSE PAYROLL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Days Worked</td>
<td>- 292</td>
</tr>
<tr>
<td>Sundays</td>
<td>- 52</td>
</tr>
<tr>
<td>Holidays</td>
<td>- 6</td>
</tr>
<tr>
<td>Days Lost to Strike, etc.</td>
<td>- 15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Men Jan. 1, 1951</th>
<th>New Hire Separations (Helpers only)</th>
<th>Total Hrs. Worked</th>
<th>Total Shifts (Statistical)</th>
<th>Total Men Dec. 31 1951</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runners 22</td>
<td>0</td>
<td>4</td>
<td>48,290-1/2</td>
<td>248-3/4</td>
</tr>
<tr>
<td>Helpers 22</td>
<td>18</td>
<td>9</td>
<td>57,216-3/4</td>
<td>294-3/4</td>
</tr>
<tr>
<td>Total 44</td>
<td>18</td>
<td>13</td>
<td>105,507-1/4</td>
<td>- - -</td>
</tr>
</tbody>
</table>

The Department employed a total of 12 professional geologists including Messrs. Derby and Boyum. Prior to June, the staff consisted of 7 permanent geologists. In June, 3 additional members were added. In the fall, 2 additional geologists became permanent staff members. By December, 2 of the staff members, Messrs. Dave and Simon were transferred to the Mather Mine property as operating engineers. This left a net of 10 permanent staff members, an increase of 3 over June. It is interesting to note that at the end of the year, our most experienced geologists had been with us a year and a half.
GEOLOGICAL DEPARTMENT - SUMMER 1951


Middle Row: R. W. Riedel, R. M. Becker, B. H. Boyum, Mrs. E. Fandrem, Mr. E. L. Derby, Jr.,

Front Row:  J. F. McAleer, G. J. Anderson, G. H. Olson, L. E. Price, W. W. Sternitzky,
            K. H. Johnson, T. T. Quirke, Jr., W. H. Tidd, B. G. Cain
The following tabulation, Table III, shows the distribution of the professional members of the Geological Department by projects, as of the end of the year.

DISTRIBUTION OF PROFESSIONAL GEOLOGICAL STAFF

AS OF DECEMBER 31, 1951

MICHIGAN

Operating Mines

Athens-------------------Kenneth H. Johnson
Cambria-Jackson----------Kenneth H. Johnson
Cliffs Shaft-------------Robert M. Becker
Lloyd---------------------Rolland L. Blake
Maas--------------------Kenneth H. Johnson
Mather Mine "A" Shaft-----David M. Bennett
Mather Mine "B" Shaft-----Gerald J. Anderson
Neguanee----------------Kenneth H. Johnson
Ohio----------------------Robert W. Riedel
Spies---------------------Robert W. Riedel
Tilden---------------------Kenneth H. Johnson

Exploration Projects

Bunker Hill---------------Kenneth H. Johnson
Cascade---------------------Kenneth H. Johnson
Empire---------------------Kenneth H. Johnson
Fitch-Saginaw-------------Rolland L. Blake
Gwinn---------------------Rolland L. Blake
Hilltop-------------------Robert W. Riedel
Humboldt-----------------Rolland L. Blake
Menominee Range, General--Robert W. Riedel
Michigamme Mine-----------Rolland L. Blake
Michigamme River----------Robert W. Riedel
North Champion------------Rolland L. Blake
Smyth Oval----------------Robert W. Riedel
Teal Lake----------------Kenneth H. Johnson
Sec. 4, 47-27 (Deep)------Joseph L. Patrick
Sec. 5, 6, 47-27---------Joseph L. Patrick
Sec. 8-9, 47-27-----------Robert M. Becker
Sec. 11-12, 47-27--------Joseph L. Patrick
Sec. 13, 43-35------------Robert W. Riedel
Sec. 25, 43-35------------Robert W. Riedel

MINNESOTA - GENERAL

E. L. Derby, Jr.
B. H. Boyum

CANADA - GENERAL

E. L. Derby, Jr.
B. H. Boyum
R. W. Riedel

VENEZUELA - GENERAL

Eric J. Rex
II. GEOLOGICAL FIELD WORK

For the most part, our geologic field work consisted of two-man reconnaissance parties. One member acted as geologist and the other as a compassman. Their work consisted of running sun-dial compass survey lines, mapping outcrops, dumps and pits, sampling iron-formation and collecting representative hand specimens of all rock types encountered.

A. Michigan

We employed 5 two-man field parties in Michigan during the summer of 1951.

1. Cascade District - A total of 29\(\frac{1}{2}\) miles of line were brushed in Sections 19, 20, 21, 22, 29 and 32. The outcrops were mapped and the iron-formation sampled along all but 1\(\frac{1}{2}\) miles of this line. The lines not completed were in Sec. 22.

A total of 57 samples were sent to the Metallurgical Research Laboratory for testing. Fifty-one of the samples were from outcrops and six were from dumps. Five of the dumps sampled were from old pits south and east of Palmer. The remaining sample was from the Platt mine dump.

2. Michigamme River Area - The 1951 field work consisted of approximately 4500 ft. of reconnaissance mapping at 1" = 132' and about 35 acres of plane tabling at 1" = 50' on the Norman property (Sec. 30, 47-30), about 8300 ft. of reconnaissance mapping at 1" = 132' on the Magnetic Mine property (Sec. 20, 47-30), and on the Michigamme River area proper approximately 794 acres of land was completely mapped in detail at 1" = 132'. The Norman was leased from the fee owners, the Magnetic was part of the state lease, and the Michigamme River Area proper was composed of land owned in fee by us, lands owned in fee by The Ford Motor Co., and lands leased from the state along with the Magnetic. The purpose of the exploration was to prove up any body of iron-formation of minable width that could be beneficiated and thereby become an economic deposit. Samples were taken of all iron-formation outcrops, test pits, dumps, trenches and shafts, and of the 28 samples taken, 16 were amenable to froth flotation and were classified as "concentratable" by the Metallurgical Department.

3. Michigamme District - During the summer field season in 1951 approximately 42,000 ft. of traverse line was run and mapped geologically at 1" = 132' in Sec. 15, 16, 17, 21, 22, 23 and 26 in 48-31. This area lies north of the Ohio Mine and south of the graywackes and quartzite below the Negaunee iron-formation and was explored between Three Lakes and the west line of the Spurr Mine property in Sec. 24, 48-31. The only outcrops of iron-formation which could be sampled were those which one sees along U.S.41 by the Ohio Mine road. This iron-formation was sampled in the hopes that it might respond to some concentration method and if that were the case an attempt would be made to prove up a body of minable width for an operation. Three samples were taken and of the three only one was encouraging and was classified as "favorable"
by the Metallurgical Department; the other two samples were classi-
ified as "no good". The material has a high ratio of iron and silica
and even at finer grinds than the standard 100 mesh it is doubtful
if the results would be much more encouraging.

4. Dead River Basin - During portion III of the 1951 season, one
day was spent in the field locating outcrops and taking samples of
the iron-formation in the Silver Lake Basin. This geological fea-
ture is a synclinorium, the long axis of which extends from the
Hoist Dam to Silver Lake, - about 16 miles, and is approximately 5
miles wide from limb to limb. It contains the Negaunee iron-forma-
tion which, where known, is relatively thin and was mapped by the
eminent E. E. White in 1907. Only one iron-formation outcrop was
located and sampled; - this was on the Hoist Dam road and the con-
centrate results are not available at this time. Although the known
iron-formation is relatively thin and fairly lean in iron, the over-
all area does hold some measure of promise and future work is cer-
tainly warranted.

5. Green Creek - After the aerial magnetic work was completed
over that area south of the Tilden and between Cwinn and Republic,
an attempt was made to correlate the magnetic pattern with known
geology to form regional control for further interpretation. One
area around Green's Creek south of Palmer was known to contain
ferruginous sediments and these were mapped in the field. The
sediments consisted of a ferruginous quartzite under, and a graph-
itic argillite over a thin, well oxidized iron-formation all en-
closed in the granite. An attempt was made to correlate this
material with the magnetic pattern, but could not be done. The
long thru-going lows on the magnetic maps are caused by basic
dikes - this was the only positive fact borne out by the field
work before the snow became excessive.

6. Miscellaneous Reconnaissance

   a. Michigamme Mountain, O.E. 1014 - One day was devoted to
the sampling of exposures of iron-formation in the area known as
Michigamme Mountain located in the NE\(^{2}\) of Sec. 4, T 43, R 31,
Iron County.

   A composite sample was made of the gathered material and
submitted to the Metallurgical Laboratory for testing. The re-
results obtained were as follows:

<table>
<thead>
<tr>
<th>Crude % Fe</th>
<th>Magnetic Concentrate % Wt.</th>
<th>% Fe</th>
<th>% SiO(_2)</th>
<th>Tail. % Fe</th>
<th>% Fe Rec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.80</td>
<td>30.64</td>
<td>61.90</td>
<td>10.48</td>
<td>18.50</td>
<td>59.65</td>
</tr>
</tbody>
</table>
b. The Shouldice, O. E. 1013 - The outcrop areas of the Shouldice, O. E. 1013, NE* of NW* of Sec. 21, 43-35, were sampled. The sample was submitted to the Metallurgical Laboratory for testing. The results were not too satisfactory as the material does not lend itself to magnetic concentration:

<table>
<thead>
<tr>
<th>Crude</th>
<th>Magnetic Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Fe</td>
<td>% Wt. % Fe % SiO2 Tall. % Fe</td>
</tr>
<tr>
<td>34.52</td>
<td>1.75 66.00 0.98 33.30</td>
</tr>
</tbody>
</table>

c. St. Lawrence Mine - Two samples were submitted to the Research Laboratory from material gathered from the St. Lawrence open pit mine located in the NW* of Sec. 5, 47-27.

Only a small proportion of the material was reported as magnetic. Flotation tests indicate that some concentration was effected; however, the low crude iron content definitely limited the recoveries obtainable.

d. Cliffs Shaft Area, Sec. 8, 47-27 - Two dump samples were obtained from an outcrop and dump located in the City Park, Sec. 8, 47-27. The material is of the hard ore type.

The crude and concentration results are as follows:

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Crude</th>
<th>Magnetic Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fe % Wt.</td>
<td>Fe</td>
</tr>
<tr>
<td>MX 1032</td>
<td>43.7</td>
<td>14.33</td>
</tr>
<tr>
<td>MX 1033</td>
<td>49.2</td>
<td>15.88</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Froth Flotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Wt. % Fe % SiO2 % Fe Rec.</td>
</tr>
<tr>
<td>MX 1032</td>
</tr>
<tr>
<td>MX 1033</td>
</tr>
</tbody>
</table>

The future plans for the area include drilling of at least one angle hole to test the extent and position of the iron-formation.

B. Minnesota

During the year 1951, no geological field work was carried out in Minnesota either by the permanent personnel or by temporary summer staff.

C. Canada

During the year 1951 the Company initiated an expanded exploration program in Canada. Dr. M. W. Bartley was engaged as chief consultant and Dr. J. M. Neilson was employed as a geologist for the summer.
The year 1951 is notable in Canadian exploration also as it marks the beginning of an aggressive policy concerning exploration and acquisition. Dr. Neilson devoted the greater part of his time to a review of the available information in the various governmental and educational institutions in Canada. It is interesting to note the great increase in land offers and outside explorations investigated during the year. (See Part VII of this report).

1. Ontario

Nemegos - Two days were spent in the field with Dr. M. W. Bartley, our Canadian consultant, investigating Land Offers 2701 and 2639, near Nemegos station on the C. P. R., 160 miles northwest of Sudbury. The deposits were of titaniferous magnetite and the available trenches and pits were sampled. The twelve samples taken were tested by the Metallurgical Department and although a good iron product could be made, the T102 was excessive and the offers were both declined and referred to National Lead who is interested in titanium prospects assaying 10%* in T102.

2. Venezuela

In May, 1951, the preliminary reconnaissance of the iron ore occurrences of Venezuela was conducted by Messrs. Stanley W. Sundeen and Robert E. Cannon. Additional field work was carried out in November and December by Messrs. Eric J. Rex and Burton H. Boyum. The latter work was principally in conjunction with Land Offer 2644, El Trueno, and Outside Explorations 1018 and 1019, El Pao and Cerro Bolivar, respectively.

III. GEOPHYSICAL FIELD WORK

Geophysical field work in 1951 was confined to magnetic prospecting. Both the Ruska Magnetometer and Hotchkiss Superdip were employed. Generally, stations were occupied every 50' along the traverse lines. Data were reduced and plotted in both plan and profile.

A. Michigan

1. Cascade District

It was planned to conduct geophysical prospecting of the magnetic type in the Cascade District during 1951. The summer field work was concluded before the program got underway and hence the work was deferred until 1952.

2. Michigamme River Area

The outcrops as mapped in this area were not sufficient to intelligently locate the hanging wall contact of the iron-formation and so some geophysical method was to be employed. The one outstanding physical property of the iron-formation and its neighboring rocks is the magnetic susceptibility. This was high in the iron-formation and low in the other rocks and for this reason magnetic profiles would be very helpful in delineating the iron-formation and locating diamond drill holes.
The instrument used was the Hotchkiss superdip on loan from the U. S. G. S. office in Iron River and was adjusted to compare with the M. C. M. & T. instrument for which W. A. Longacre had prepared conversion curves. The instrument was oriented perpendicular to the magnetic meridian at each of the 50 ft. stations and thus the relative vertical intensities of these stations were obtained and tied in to our Marquette Range magnetic system by occupying either magnetic prime #22, 31 or 31-A.

On the Norman property, about 4,500 ft. of line was run, on the Magnetic Mine land about 8300 ft. of traverse was run, and on the Michigamme River area proper a little over 35,500 ft. of line was run. These geophysical traverses were made on the traverse lines already cut for the geological mapping and in all about 970 observations were made.

Magnetic profiles are relatively cheap and easy to produce and are invaluable in making a geological interpretation.

3. Michigamme District

The same system was followed in this district as on the Michigamme River area for the geophysical prospecting which was entirely magnetics with the Hotchkiss superdip. In this district we used the Ohio Mine magnetic prime #16 for a base and completed approximately 42,000 ft. of traverse with 840 separate observations.

Here again the data was good and in addition to delineating the Negaunee iron-formation along the highway (U.S. 41) they disclosed a moderate magnetic high between the Negaunee and the Bijiki iron-formation which is quite probably the Greenwood iron-formation.

An attempt to extend the reserve of the Ohio Mine thru the Beaufort property led to about 2000 ft. of north-south traverse with the Ruska magnetometer. The reduced data was used to locate drill holes.

4. Green Creek

The Aero Service Corp. of Pittsburgh flew an aerial magnetometer survey of an area composed of all of T. 45 N, R. 26 W., 45-27, 45-28, 45-29, 46-26, 46-27, 46-28, 46-29, and south half of Townships 47-26, 47-27, 47-28, and 47-29. This is roughly the entire area from Gwinn to Republic and 15 miles south of the Tilden Mine. The flight was made using standard procedure and equipment. The flight lines were north-south, 1/2 miles apart and flown at approximately 500 ft. above the land surface. A special instrument was in use on the flight and was called a gradiometer. It made a separate record from the magnetic record and recorded the variance in the rate of change on the slope of any anomaly. With this it is possible to accurately map any minor anomalies which are superimposed on a large one.
The finished contoured maps of the 360 sq. mi. (10 townships) were submitted and are to be interpreted now. We are particularly looking for an anomaly which may be caused by a large basin of sediments and included ore in the granites. The anomaly could be a high or a low and our work at Green's Creek was inconclusive mainly because the area was so small and shallow that at 500 ft. the anomaly was marked by the regional gradient. No significant anomaly was found to indicate another sedimentary basin and thus rules out this possibility, based upon present interpretation.

5. Ishpeming-Negaunee Seismic

In June, four companies on the Marquette Range joined in a cooperative geophysical research program with the staff of the M. C. M. & T. This consisted of the investigation by refraction seismic prospecting of two areas. These areas were adjacent to the Norris Mine and Maas Mine. The goal of the project was to compare the depth determinations by refraction seismic prospecting with known depths from drill holes. The four companies involved were the Inland Steel, Jones and Laughlin, North Range and The Cleveland-Cliffs. In general, the depth determinations checked within 10% of the known values.

B. Minnesota

The distribution of field work was as follows:

<table>
<thead>
<tr>
<th>Type of Survey</th>
<th>Days</th>
<th>Length of Traverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road traverse, magnetometer</td>
<td>11.5</td>
<td>121 miles</td>
</tr>
<tr>
<td>Profile traverse, magnetometer</td>
<td>4.5</td>
<td>25,900 feet</td>
</tr>
<tr>
<td>Profile traverse, superdip</td>
<td>5</td>
<td>26,400 feet</td>
</tr>
<tr>
<td>Scouting, superdip</td>
<td>1</td>
<td>4,000 feet</td>
</tr>
</tbody>
</table>

The road traverse averaged about 10.5 miles per day. The magnetometer profile traverse averaged about 5750 feet per day. The superdip traverse averaged nearly 5100 feet per day. The station interval in the road traverse was 1/10 mile, 2/10 mile, or 1/4 mile, depending on the gradient of the magnetic field. About half of the magnetometer profile was run at 50-ft. station interval, and the remainder at 100-ft. station interval. Almost all of the superdip work was done at 50-ft. station interval.

1. Mesabi Range

a. Mahtowa Township Magnetometer Survey (Land Offer 2663)- The magnetic measurements in this area did not disclose any pattern of anomalies that could be considered favorable for further exploration. One broad anomaly of moderate amplitude was discovered in the northwest corner of the township. No outcrops were found along the roads in this part of the surveyed area, and the cause of the anomaly is unknown. One possibility is the presence of iron-formation. In the rest of the surveyed area, the uniformity of the magnetic field, and the presence of occasional outcrops of slate, would indicate that extensive magnetic mineralization is unlikely.
Some casual magnetic observations in the Kettle River area disclosed an elevation in the level of the magnetic field. This area appeared more interesting magnetically, but inquiry revealed that most of the surrounding land had been placed under option. One small drill-rig was seen in the vicinity. Presumably, this was the location of the iron ore discovery as reported in the newspapers later in the summer.

b. Eveleth Anticlinal Axis and Vicinity Magnetometer Survey. (Land Offer 2680) - This survey was undertaken to check, to complement, and to extend the survey made by G. M. Schwartz in 1942. The original survey had been made at the suggestion of M. P. Walle.

The new survey confirmed in general the anomalous magnetic pattern as published by Dr. Schwartz except in a few scattered areas; one notable lack of correlation being along the west line of T. 56 N., R. 18 W., where the earlier survey had indicated a greater extension of the "zone of magnetic attraction" than could be found in the recent survey.

In some areas not covered by Schwartz, additional anomalies were found. Those in T. 58 N., R. 18 W. seem especially interesting and perhaps warrant further investigation.

It would appear that the principal zone of magnetic highs is clearly related to the Eveleth anticline. The magnetically low area southwesterly of the axis of magnetic highs, and in the Peary area, is also very likely related to the anticlinal structure. It was concluded that the first drilling should investigate these anomalies.

c. Supplementary Magnetometer Survey, Forbes–Peary Area. (Land Offer 2680) - Following the acquisition of State lands in the Forbes area, additional magnetic work was done to establish drill-hole locations in relation to the magnetics, and to investigate the easterly extent of the magnetically low zone which exists in the Peary area. It was found that the low anomaly extends less than three miles to the east of U. S. Highway 33.

The magnetic traverse for accurate determination of optimum drill-hole location on the Forbes anomaly was run along the approximate diagonal of Section 36, T. 57 N., R. 18 W. through the northwest corner, and extended from this corner along the approximate diagonal of the south 1/2 of Section 26, T. 57 N., R. 18 W. From the magnetic profile along this line, two drill-hole locations were chosen; one in the magnetic low and near the southeast corner of Section 36, and one in the magnetic high and 1000 feet northwesterly from the northwest corner of Section 36.

d. Magnetometer Survey, Summerfield Property (Land Offer 2678) - This survey was made principally in two forty-acre tracts about four miles northeast of Hibbing and just south of the Douglass mine. The objective was to determine from the magnetics the best location for a drill-hole.
The north forty, the SE-SE of Section 34, 58-20, appears more likely to contain iron-formation than the south forty, the NE-NE of Section 3, 57-20. In the latter area, the magnetic field has a gentle gradient to the northeast. In the north forty the general gradient is to the north, but is distributed considerably by alternate highs and lows, especially in the eastern half of the tract.

The center of the SE-SE of Section 34, 58-20 is in a relative magnetic low, partly surrounded by magnetic highs. This point is considered the best location for possible drilling. This estimate is based on the magnetic map only, since no specific geological information could be obtained.

e. Magnetometer Survey, Wanless Mine Area - This survey was made over an area near the Wanless Mine which had been proposed as a dump site. The magnetometer survey indicated that the underlying material is very magnetic, and presumably taconite. A nearby drill-hole, C-8, is in taconite and magnetic readings taken at and near this location show an elevated level of magnetic field with considerable variation from station to station. The traverse lines over the surveyed area were 400 ft. apart and the station interval was 50 ft. Large and erratic variations in a distance of 50 ft. along the lines made contouring of the isodynamic lines an almost impossible task with the large separation of the lines. However, since no indications of non-magnetic material were encountered on any of the lines, it is believed that the entire area is underlain with magnetic taconite.

2. Vermilion Range

Superdip Survey, Thompson Property, Tower-Soudan Area (Land Offer 261) - In the scouting trip on July 17, 1951, random superdip traverses revealed the presence of very large magnetic anomalies. It was decided to run a reasonably detailed superdip survey over the area, and to this end, a 3/4 mile base line was established along the north property line, from which north-south lines were run to approximately the south boundary of the 120-acre tract. These lines were 200 feet apart. Superdip readings were taken at 50-ft. station interval along these lines, and in addition the western 1/4 mile of the base line was surveyed magnetically at 100-ft. station interval. The superdip readings were converted to gammas and plotted both in plan and profile.

The resulting magnetic picture for the area is highly interesting, and would provide an excellent text-book example of magnetic exploration. The strike of the formations is indicated quite clearly; the dips are not quite so clear, but evidently are generally very steep. The magnitude of the magnetic highs is such that the presence of underlying iron-formation containing considerable magnetite is virtually a certainty. Whether this material is ore, or concentratable iron-formation, or worthless at present, can only be determined by drilling. In addition, the drilling would provide more exact information on the structure, since the integrating nature of magnetic variations tends to mask some detail.
One interesting by-product of the survey was the opportunity to compare ground magnetics with aeromagnetics over the same small area. The aerial survey showed isodynamic contours over the Thompson Property which followed the strike of the formations quite closely, but did not show the maxima, minima, and other important details as brought out clearly by the ground survey. The explanation of these differences involves many factors. The aerial magnetometer measures changes in the total magnetic intensity while the ground instrument measures changes in the vertical component of the total intensity. At higher elevation, diffraction effects become more evident, that is, a number of separated anomalies on the ground may become a single broad anomaly at 500 or 1000 ft. elevation. In airborne work, shift of anomaly patterns may occur due to the dip of the earth's magnetic field, and also due to errors in mapping where landmarks are widely scattered. In addition, sharp anomalies on the ground are sometimes damped out partially in aeromagnetic surveying due to inertia in the plotting system.

It is believed that aeromagnetics and ground magnetics are complementary and that each has its function in magnetic exploration. Large scale reconnaissance of big areas is the apparent function of the air-borne magnetometer while detailed magnetic studies of smaller areas is the function of ground magnetics. For example, the large scale magnetic pattern to the south-east of Tower, Minnesota, as shown by the aeromagnetic survey, could be shown by ground work only at the cost of excessive amounts of time, labor, and money. On the other hand, the detail as brought out by the ground magnetic survey over the Thompson Property could not be obtained by aeromagnetic surveying at its present state of development.

C. Canada

A limited amount of magnetic prospecting was conducted at the St. Adele property, Outside Exploration #999. This was done by Mr. T. T. Quirke, Jr., employing a Sharpe SuperDip. This work was of little value because of the instrumental difficulties encountered.

**TABLE IV**

The following tabulation, Table IV, shows the summary of the geophysical activity for 1951:

<table>
<thead>
<tr>
<th></th>
<th>Man-months</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MICHIGAN</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Magnetic</td>
<td>4.0</td>
<td>$1,243.57</td>
</tr>
<tr>
<td>Aeromagnetic</td>
<td>11.0</td>
<td>$18,551.25</td>
</tr>
<tr>
<td>Seismic</td>
<td>1.0</td>
<td>$500.00</td>
</tr>
<tr>
<td></td>
<td>16.0</td>
<td>$20,294.82</td>
</tr>
<tr>
<td><strong>MINNESOTA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Magnetic</td>
<td>4.8</td>
<td>$4,224.77</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>20.8</td>
<td>$24,519.59</td>
</tr>
</tbody>
</table>

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### IV. EXPLORATION DRILLING DIVISION

The newly formed Exploratory Drilling Division is the result of the efforts made by the Chief Geologist to streamline the Departmental Responsibilities. The prime function of the Exploratory Drilling Division is to expedite the drilling phase of the exploration once the drilling campaign has been laid out by the Geologist. The prime responsibility of the Exploratory Drilling Division is the drilling equipment, drilling personnel and contractual arrangement for any drilling that is to be performed.

The principal drilling method employed is that of diamond core drilling. Variations from the normal drilling methods include standing, churn drilling, rotary mud drilling, structure drilling, and combinations thereof.

The Geologists assigned to the various explorations, be it surface or underground, afford the direct tie between the geological requirements and the drilling operations.

#### 1. Diamond Cost

The following Table V represents an analysis of diamond bit costs at the various locations and the respective hole sizes:

<table>
<thead>
<tr>
<th>CONTRACT</th>
<th>EX</th>
<th>SX</th>
<th>NY</th>
<th>PER FT. COST OF DIAMOND BITS USED IN 1951</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athena</td>
<td>165</td>
<td>$1777.39</td>
<td>$7.09</td>
<td>2750</td>
</tr>
<tr>
<td>Narber &quot;A&quot;</td>
<td>2156</td>
<td>6000.13</td>
<td>2.78</td>
<td>2975</td>
</tr>
<tr>
<td>Narber &quot;B&quot;</td>
<td>1171</td>
<td>4339.68</td>
<td>2.60</td>
<td>226</td>
</tr>
<tr>
<td>Cliffs Shaft</td>
<td>1221</td>
<td>$5394.86</td>
<td>$4.42</td>
<td>563</td>
</tr>
<tr>
<td>Spies</td>
<td>1221</td>
<td>$5394.86</td>
<td>$4.42</td>
<td>563</td>
</tr>
<tr>
<td>19 - 74</td>
<td>1333</td>
<td>1034.53</td>
<td>3.21</td>
<td>328</td>
</tr>
<tr>
<td>21 - 2</td>
<td>1301</td>
<td>1243.17</td>
<td>1.19</td>
<td>1064</td>
</tr>
<tr>
<td>27 - 23</td>
<td>103</td>
<td>1078.70</td>
<td>3.21</td>
<td>328</td>
</tr>
<tr>
<td>27 - 23a</td>
<td>113</td>
<td>277.11</td>
<td>0.67</td>
<td>140</td>
</tr>
<tr>
<td>29 - 14</td>
<td>1156</td>
<td>$53764.03</td>
<td>$3.00</td>
<td></td>
</tr>
</tbody>
</table>

$2.52 Cost Per Foot for All Bits Used in 1951.
2. Diamond Inventory - Hand Setting

The following Table VI shows the distribution of carbon and ballas borts for the year 1951.

TABLE VI

<table>
<thead>
<tr>
<th></th>
<th>CARBON (Hand Setting)</th>
<th>BALLAS BORT (Hand Setting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Hand 1/1/51</td>
<td>858.24</td>
<td>$63,629.89</td>
</tr>
<tr>
<td>Purchased 1951</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>858.24</td>
<td>$63,629.89</td>
</tr>
</tbody>
</table>

|                   | TOTAL | 858.24 | $63,629.89 | $78.72 | 40.89 | $1,077.17 | $99.72 |

|                   | Rts. | Amount | Per Rt. |
| On Hand 12/31/51  | 658.24 | $56,629.89 | $78.72 |
| Used 1951 (Loss)  | --   | --      | --      |
|                   | 658.24 | $56,629.89 | $78.72 |

DISTRIBUTION OF INVENTORY: Loose Carbon, Carbon set in bites, loose Ballas (C. O. I. Co.)

3. Diamond Inventory - Mechanical Setting

The following tabulation shows the overall distribution of all types of diamonds used and on hand during the year 1951.

TABLE VII

<table>
<thead>
<tr>
<th></th>
<th>SCRAP CARBON</th>
<th>OONGO</th>
<th>LONGYEAR</th>
<th>&quot;A&quot; GRADE</th>
<th>&quot;B&quot; GRADE</th>
<th>TOTAL BORTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Hand 1/1/51</td>
<td>306.71</td>
<td>$4,569.91</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Purchased 1951</td>
<td>---</td>
<td>---</td>
<td>390.96</td>
<td>$2,115.76</td>
<td>371.01</td>
<td>$1,111.91</td>
</tr>
<tr>
<td></td>
<td>306.71</td>
<td>$4,569.91</td>
<td>---</td>
<td>---</td>
<td>390.96</td>
<td>$2,115.76</td>
</tr>
</tbody>
</table>

| Used 1951 (Loss)  | 46.51 | 79.34 | 44.39 | 265.90 | 65.75 | 736.87 | 10,706.72 | 91,663.14 | 11,600.38 | 113,679.49 | 12,023.56 | 104,800.07 | 128,626.11 | 104,800.07 |
|                   | 302.20 | $4,400.07 | 106.44 | 4,079.96 | 308.64 | $3,395.04 | 29,556,368,399,183 | 7,076,15 | $60,136.75 | 37,506,312,795.63 |

DISTRIBUTION OF INVENTORY IN CARATS

<table>
<thead>
<tr>
<th></th>
<th>SCRAP CARBON</th>
<th>OONGO</th>
<th>LONGYEAR</th>
<th>&quot;A&quot; GRADE</th>
<th>&quot;B&quot; GRADE</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lost Borts (Manufacturers)</td>
<td>60.83</td>
<td>173.82</td>
<td>---</td>
<td>---</td>
<td>6,933.56</td>
<td>953.45</td>
</tr>
<tr>
<td>Lost Borts (C. O. I. Co.)</td>
<td>18.97</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>200.00</td>
<td>102.85</td>
</tr>
<tr>
<td>Salvage Reports Pending</td>
<td>31.54</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>
4. Plant Account

Table VIII is merely an excerpt from the 1951 Financial Statement.

<table>
<thead>
<tr>
<th>Account</th>
<th>Account &quot;B&quot;</th>
<th>Account &quot;C&quot;</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>End 1950</td>
<td>$ 17,971.64</td>
<td>$ 115,779.92</td>
<td>$ 114,830.10</td>
</tr>
<tr>
<td>End 1951</td>
<td>23,338.39</td>
<td>129,354.12</td>
<td>159,906.60</td>
</tr>
</tbody>
</table>

Group "A" - Life not exceeding 2 years.
Group "B" - Life not exceeding 10 years.
Group "C" - Rods & Casing - Depreciated on footage basis.

Rental charges (Per shift and per foot charges to cover depreciation and maintenance cost) amounted to $26,835.47.

V. SURFACE EXPLORATION

A. Michigan

1. Introduction - The term "exploration" as we use it, includes, where necessary, geological mapping, geophysical prospecting, and drilling. The details of the geological mapping and the geophysical prospecting are covered in Sections II and III of this report. The principal part of this section is devoted to drilling and to the combined techniques.

Our surface exploration may be divided into two general types, - the shallow exploration for beneficiating ores and the deep exploration for direct shipping ores. During the year, we employed 1 Company rig and 3 Longyear contract rigs in the beneficiating ore exploration. In the exploration for the direct shipping ore we employed 7 Company rigs and 5 contract rigs for a total of 12 drill rigs during the year.
2. **Summary of Drilling**

The following tabulation shows the Summary of Drilling:

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>HOLES</th>
<th>DEPT.</th>
<th>DIAMOND</th>
<th>CUMULATIVE</th>
<th>1ST CLASS CUM.</th>
<th>TOTAL</th>
<th>COST/FT</th>
<th>TOTAL</th>
<th>COST/FT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sec. 29, 17-27</td>
<td>2 &amp; 3</td>
<td>C. C. I.</td>
<td>34</td>
<td>3221</td>
<td>3255</td>
<td>10</td>
<td>.307</td>
<td>$34,025.22</td>
<td>$10.45</td>
</tr>
<tr>
<td>Sec. 2, 17-27</td>
<td>66 &amp; 67</td>
<td>E. J. L.</td>
<td>74</td>
<td>1231</td>
<td>1305</td>
<td></td>
<td></td>
<td>13,041.30</td>
<td>9.59</td>
</tr>
<tr>
<td>Sec. 4, 17-27</td>
<td>12 &amp; 43</td>
<td>C. C. I.</td>
<td>2</td>
<td>7022</td>
<td>7023</td>
<td>82</td>
<td>1.168</td>
<td>92,440.60</td>
<td>13.44</td>
</tr>
<tr>
<td>Sec. 9, 17-27</td>
<td>58</td>
<td>C. C. I.</td>
<td></td>
<td>2359</td>
<td>2359</td>
<td></td>
<td></td>
<td>19,572.78</td>
<td>8.30</td>
</tr>
<tr>
<td>Sec. 9, 17-27</td>
<td>59, 60, 61</td>
<td>E. J. L.</td>
<td>339</td>
<td>3300</td>
<td>3639</td>
<td>34</td>
<td>2.110</td>
<td>37,610.77</td>
<td>10.97</td>
</tr>
<tr>
<td>Total Drilling Sec. 9</td>
<td>58, 59, 60, 61</td>
<td>C.C.I. &amp; E.J.L.</td>
<td>339</td>
<td>3659</td>
<td>3970</td>
<td>34</td>
<td>1.856</td>
<td>37,485.55</td>
<td>9.34</td>
</tr>
<tr>
<td>Sec. 10, 17-27</td>
<td>25 &amp; 26</td>
<td>C. C. I.</td>
<td></td>
<td>126.5</td>
<td>126.5</td>
<td></td>
<td></td>
<td>300.00</td>
<td></td>
</tr>
<tr>
<td>Sec. 11, 17-27</td>
<td>11, 12, 13, 20</td>
<td>C. C. I.</td>
<td>21</td>
<td>7196</td>
<td>7217</td>
<td>5</td>
<td>.069</td>
<td>85,120.23</td>
<td>11.79</td>
</tr>
<tr>
<td>Sec. 11, 17-27</td>
<td>(19, 19, 15)</td>
<td>E. J. L.</td>
<td>120</td>
<td>12604</td>
<td>12724</td>
<td>86</td>
<td>.676</td>
<td>151,124.36</td>
<td>11.86</td>
</tr>
<tr>
<td>Total Drilling Sec. 11</td>
<td>(11, 12, 13, 14)</td>
<td>C. C. I. &amp; E. J. L.</td>
<td>161</td>
<td>19800</td>
<td>19961</td>
<td>91</td>
<td>1.656</td>
<td>236,264.19</td>
<td>11.85</td>
</tr>
<tr>
<td>Sec. 27, 17-27</td>
<td>23</td>
<td>C. C. I.</td>
<td></td>
<td>331</td>
<td>331</td>
<td></td>
<td></td>
<td>9,612.16</td>
<td>29.04</td>
</tr>
<tr>
<td>Sec. 2, 17-30</td>
<td>1</td>
<td>E. J. L.</td>
<td>40</td>
<td>3777</td>
<td>417</td>
<td></td>
<td></td>
<td>1,830.24</td>
<td>6.71</td>
</tr>
<tr>
<td>Sec. 20, 17-30</td>
<td>6, 7, 8, 9, &amp; 5</td>
<td>E. J. L.</td>
<td>435</td>
<td>1780</td>
<td>2195</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 30, 17-30</td>
<td>1, 2, 3, 9, &amp; 5</td>
<td>E. J. L.</td>
<td>258</td>
<td>3003</td>
<td>3261</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 31, 17-30</td>
<td>3, 2, 3, 4</td>
<td>E. J. L.</td>
<td>90</td>
<td>1532</td>
<td>1622</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Drilling Sec. 20, 30 &amp; 31, 17-30</td>
<td>763</td>
<td>6295</td>
<td>7058</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE IX - (Continued)

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>HOLES</th>
<th>ROCK</th>
<th>OVER-DUCTION</th>
<th>DIAMOND DRILLING</th>
<th>TOTAL FOOTAGE</th>
<th>1ST CLASS ORE</th>
<th>TOTAL COST &quot;A&quot;</th>
<th>&quot;A&quot;</th>
<th>TOTAL COST &quot;B&quot;</th>
<th>&quot;B&quot;</th>
<th>COST/FT. &quot;B&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sec. 19, 48-30</td>
<td>8</td>
<td>C. L. I.</td>
<td>294</td>
<td>294</td>
<td></td>
<td></td>
<td>$5,283.82</td>
<td>17.97</td>
<td>$5,962.17</td>
<td>20.28</td>
<td></td>
</tr>
<tr>
<td>(Richgama Mine)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 22, 48-31</td>
<td>9, 10, 11, &amp; 12</td>
<td>E. J. L.</td>
<td>159</td>
<td>26.6</td>
<td>405</td>
<td></td>
<td>4,905.23</td>
<td>11.87</td>
<td>5,583.79</td>
<td>13.79</td>
<td></td>
</tr>
<tr>
<td>Sec. 26, 43-35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. 27, 43-35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Sec. 26 &amp; 27, 43-35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>104,408.14</td>
<td>7.75</td>
<td>107,360.75</td>
<td>7.97</td>
<td></td>
</tr>
<tr>
<td>TOTAL SURFACE DRILLING</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>57,586.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Recap by Organisation

The following tabulation shows the Recap by Organisation:

### TABLE X

<table>
<thead>
<tr>
<th>DEEP HOLE DIRECT SHIPING</th>
<th>NO. RYDOS</th>
<th>FOOTAGE</th>
<th>% OF TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. L. I.</td>
<td>6</td>
<td>19,894</td>
<td>66.1</td>
</tr>
<tr>
<td>Contract</td>
<td>1</td>
<td>10,072</td>
<td>33.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>29,966</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SHALLOW HOLE DIRECT SHIPING</th>
<th>NO. RYDOS</th>
<th>FOOTAGE</th>
<th>% OF TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. L. I.</td>
<td>3</td>
<td>19,035</td>
<td>100.0</td>
</tr>
<tr>
<td>Contract</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>19,035</td>
<td>100.0</td>
</tr>
</tbody>
</table>

### TOTAL SHALLOW DRILLING

<table>
<thead>
<tr>
<th>C. L. I.</th>
<th>FOOTAGE</th>
<th>% OF TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract</td>
<td>8,174</td>
<td>96.1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8,505</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C.C.I. Cliffs Shaft Mine Shaft Testing</th>
<th>FOOTAGE</th>
<th>% OF TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAND TOTAL SURFACE</td>
<td>57,586.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>
4. Summary of Results

a. Cascade - The exploration for direct shipping ore in the structure between the Isabella and Volunteer dikes has not been successful as yet. Excessive drill hole deviation, coupled with the negative nature of the iron-formation which makes compass tests unreliable, necessitated the drilling of hole #3 before the nature of the intrusive encountered in holes #1 and #2 could be determined.

b. Section 2, L7-27 - The program of surface exploration in Sec. 2, L7-27, was designed to test for ore above the intrusive directly south of the "A" Shaft of the Mather Mine. Two holes were drilled. Hole #66, a vertical hole, was testing the area above the intrusive and was drilled to 1249'. No ore was encountered. Hole #67 was drilled as an angle hole for structural control. These two holes completed the campaign of exploration from the surface. The area will be explored at greater depth from proposed underground workings at some future date.

c. Section 4, L7-27 - Two deep hole rigs were conducting the exploration for ore in Sec. 4, L7-27. Hole #42 was completed at a depth of 3695'. Eighty-two (82) feet of first class ore was cut in this hole. The ore was found at a considerable distance above the footwall and the full significance of its position is not known at the present time.

Hole #43 had reached a total depth of 4221' by the end of the year. Deviation, southward, occurred in the quartzite and as a result the hole did not test the area for which it was planned.

The deep hole drilling in Sec. 4, L7-27 is contributing structural information which is of great value in our search for deep ores.

d. Section 9, L7-27 - The surface drilling of Sec. 9, L7-27 is discussed in the Cliffs Shaft report under Part VI, Sub-section (d), 3rd paragraph.

e. Section 10, L7-27 - Two holes were drilled in conjunction with the proposed shaft for the Cliffs Shaft mine. These holes were testing the thickness and type of overburden through which the shaft would be sunk.

f. Section 11, L7-27 - The drilling exploration in Sec. 11, L7-27, was carried on by shallow and deep hole rigs.

The deep holes were 12, 13, 14, 14A, 19, 20 and 21 and the shallow holes were 15, 16, 17 and 18.

The first phase of exploration was concentrated in the northeast quarter of the section. The purpose was to search for structure and possible extension of the ore which was discovered in hole #9. Drilling has shown that the ore in hole #9 is confined to the northeastern part of the section. No deep ore of any significance was discovered in any of the holes.
Shallow ore was discovered in hole #14 and further exploration was conducted by holes #15, 16, 17, and 18. It appears that the ore is confined to the area drilled by holes 14, 15, and 16, and holes 17 and 18 were in different structure.

The second phase of drilling in Sec. 11, 47-27, was initiated by Holes #20 and 21, located in the northwest quarter and the southwest quarter. These holes had not reached significant depth at the end of the year.

g. Tilden - The western portion of the Tilden Area surface exploration for treating ore was completed in the early part of 1951. The metallurgical results indicated need of more research in the future.

h. North Michigamme Area - The last hole in the drilling campaign for the Michigamme Mine was completed during 1951. This was hole #8 in Sec. 19, 48-30. The sections and plan map were posted and after receiving the Metallurgical Department test work on the core, an ore and stripping estimate was made.

i. Ohio Mine - During 1951, an attempt was made to extend the reserves of the mine to the northwest through the Beaufort property. The magnetic profiles were taken on 600 ft. centers and an interpretation made. On the basis of this data, we drilled four holes totaling 375 ft. of drilling which extended the west end of the west pit 550 ft. This added material increased the reserves of concentrates by 24.9%. The stripping ratio was increased from 3.30 to 3.74.

j. Michigamme River Area

1'. Norman Mine - The iron-formation is composed of interbedded magnetite, iron-silicate, and chert and was explored for 4500 ft. along the strike by five drill holes totaling 3261 ft. of drilling in addition to the surface geological and geophysical work. The formation strikes N 15° E, dips 80° to the west, and the 425 ft. from foot to hanging contains four diorite sills which total twice as much rock as iron-formation. The Metallurgical Laboratory does not classify any of the iron-formation core as concentrateable. These facts indicate that the area does not contain an economic deposit of beneficiating iron-formation at this time.

2'. Magnetic Mine - The iron-formation on the Magnetic anticline was explored by diamond core drilling and from the magnetic profiles an iron-formation was outlined in the northern part of Sec. 20 which would be stratigraphically higher than the Negaunee near the center of the section. Five holes totaling 2177 ft. of drilling explored both of these horizons below surface and only 39 ft. of all the holes was classed as favorable by the Metallurgical Laboratory. The iron-formation was thin (120 ft. including 28 ft. of sill material) and not long (3000 ft.) There is not an economic deposit of beneficiating iron-formation on the Magnetic Mine area.
3'. Standard Mine - To the end of the year, three holes had been drilled on this area and had disclosed an iron-formation of minable width (180 ft. max.) but which did not respond to any of the metallurgical tests thus far to produce a high grade concentrate.

4'. Metropolis Mine - Only one hole had been drilled by the end of the year and the iron-formation, the thin, looked fairly good. On the Metropolis it was a specular hematite - quartzite rock. No test work has been done on this material.

In general, the drilling correlated very nicely with the surface geology and as was mentioned before, the magnetic profiles were invaluable in making a geologic interpretation and planning intelligent drill holes. In a few cases, the holes cut too much hanging wall material but this was because of either the unusual, variable high susceptibilities in the hanging sills or the depth of overburden which spread the magnetic high of the iron-formation out considerably.

k. Hilltop Exploration

During 1951, 17 holes were drilled on this exploration totaling 13,467 ft. of drilling. The ore encountered in D.D.H. #3, Sec. 26, was cut in #4, but it was deeper and much thinner. Hole # 13 cut a short run of ore but this did not persist along the strike so amounted to nothing. We have a fair idea of the ledge geology now and are following the formation to the south boundary. As of the end of 1951, no minable body of first class ore has been found on the Hilltop. The iron-formation trends roughly northeast-southwest, dips from -70° to -90° to the northwest and varies from 60 to 200 ft. in width.

B. Minnesota

The Minnesota Exploration program discussed in this report covers the work done outside of the operating properties. This drilling was not successful in finding new reserves. The work may be tabulated as follows:

TABLE XI
MINNESOTA EXPLORATION DRILLING

<table>
<thead>
<tr>
<th>LAND OFFER</th>
<th>NAME</th>
<th>HOLES</th>
<th>FOOTAGE</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>2680</td>
<td>Eveleth</td>
<td>3</td>
<td>1487</td>
<td>$19,556.37</td>
</tr>
<tr>
<td>2662</td>
<td>Wagner</td>
<td>3</td>
<td>707</td>
<td>7,659.53</td>
</tr>
<tr>
<td>2660</td>
<td>Gross-Molvin</td>
<td>5</td>
<td>750</td>
<td>10,386.34</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>11</td>
<td>2944</td>
<td>$37,602.24</td>
</tr>
</tbody>
</table>

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VI. UNDERGROUND EXPLORATION

1. Drilling

1. Summary of Drilling

The following tabulation is the summary of drilling:

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>HOLES</th>
<th>DEPT.</th>
<th>DIAMOND DRILLING</th>
<th>1ST CLASS OUT</th>
<th>TOTAL COST</th>
<th>COST/PT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athens</td>
<td>33, 45, 46</td>
<td>C. O. I.</td>
<td>547</td>
<td>27</td>
<td>$7,040.04</td>
<td>$7.92</td>
</tr>
<tr>
<td>Bunker Hill</td>
<td>5, 6, 7, 8</td>
<td>C. O. I.</td>
<td>839</td>
<td>185</td>
<td>$7,577.04</td>
<td>$8.02</td>
</tr>
<tr>
<td>Lloyd</td>
<td>185-190, Incl.</td>
<td></td>
<td>3056</td>
<td>356</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother Mine, &quot;A&quot; Shaft</td>
<td>71 - 87 &quot;</td>
<td></td>
<td>5580</td>
<td>979</td>
<td>33,176.77</td>
<td>4.54</td>
</tr>
<tr>
<td>Mother Mine, &quot;B&quot; Shaft</td>
<td>4, 11, 17 &amp; 19 C. O. I.</td>
<td></td>
<td>14453</td>
<td>3142</td>
<td>36,721.83</td>
<td>6.49</td>
</tr>
<tr>
<td>Cliffs- Shaft</td>
<td>C. O. I.</td>
<td></td>
<td>729.7</td>
<td>17.2</td>
<td>33,088.93</td>
<td>4.57</td>
</tr>
<tr>
<td>Spies</td>
<td>69, 54, 554, Odgers Co.</td>
<td>2753</td>
<td>1304</td>
<td></td>
<td>36,177.70</td>
<td>4.99</td>
</tr>
</tbody>
</table>

2. Recap by Organization

The following tabulation is the recap by organization:

<table>
<thead>
<tr>
<th>ORGANIZATION</th>
<th>NO. OF HOLES</th>
<th>FOOTAGE</th>
<th>PER CENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. C.O.I. Co.</td>
<td>3</td>
<td>4492'</td>
<td>12.5 %</td>
</tr>
<tr>
<td>1. Geol. Dept.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Mine</td>
<td>6</td>
<td>27,280'</td>
<td>76.1 %</td>
</tr>
<tr>
<td>b. Contract</td>
<td>1</td>
<td>4,077</td>
<td>11.4 %</td>
</tr>
<tr>
<td>TOTAL</td>
<td>10</td>
<td>35,819'</td>
<td>100.0 %</td>
</tr>
</tbody>
</table>

3. Summary by Properties

a. Athens Mine - Drilling from the 700 and 8th level disclosed first class ore north of the main north ore body. It is necessary to prove more tonnage by drifting and diamond drilling from 10th level before it would warrant the 600 ft. of rock drifting necessary to mine it.
b. Bunker Hill - The significant exploration consisted of
diamond drilling from the -900 sub level. It was disclosed that
the ore goes at least to a depth of -1245 ft. sea level elevation
in the north ore body on the 2100 W. coordinate.

Ore was found to occur above 10th level elevation on the
1900 W. coordinate in the south ore body as far south as the
3580 S. coordinate where it is cut off by a diorite intrusive.

C. Cambria-Jackson Mine - Geological work consisted in
routine mapping in the mining subs and in mapping the winze
and 8th level development.

d. Cliffs Shaft Mine - Underground drilling during the year
has been confined to "A" and "B" shafts above 5th level, the Section
10 and Bancroft leases and the "A" East area. The most significant
tonnage additions have been in the Bancroft and "A" East areas.
From the workings available at the present time, drilling can be
considered largely complete above 5th level "A" and "B" shafts and
in the Section 10 lease.

Limits of the Cliffs Shaft hard ore horizon have been estab-
lished to the north and south with greater precision. Nearly
E-W faults bordering the Bancroft and Section 10 leases on the
north and south respectively and bounding the "B" Shaft workings
on the north and south have removed the ore horizon above the sur-
face of erosion.

The ore horizon, dipping south, rolls back and intersects
ledge about 800' south of the south limiting fault mentioned above.
It is in this area, where the ore horizon is back below ledge,
that a short range surface drilling program was initiated to explore
for ore which could be expected above present workings. At the
end of the year the three holes that had been drilled in this area,
near the Robbins Flooring Mill, had proven up largely lean and 2nd
class conglomerate ore.

e. Lloyd Mine - Drilling in depth from the 8th level explora-
tion drift did not disclose any ore body of minable size. The
final two holes were drilled during 1951 and consisted of 1971 ft.
of drilling in two holes.

The high sulfur ore body south of the main east-west dike was
explored below 9th level by four holes which totaled 1085 ft. of
drilling and an interpretation on this data reveals some 202,125
tons to the -120 ft elevation analyzing 59.57 Fe, 0.137 phos.,
and 0.70% sulfur. This body together with a probable body north
of the dike gives a total of 267,937 tons analyzing 59.37 Fe,
0.151 phos., and 0.546 sulfur.

f. Maas Mine - Geological work for the Maas Mine consisted
of mapping in the mining subs and in seventh level development.
The mapping in 7th level indicates that the anticipated ore outlines
are essentially correct.

g. Mather Mine "A" Shaft - Diamond drilling on seventh level
was confined to west of the Mather fault, and proved up scattered
ore bodies mainly. On sixth level, holes were drilled on both "A"
Shaft and "B" Shaft property, and resulted in proving some ore for
7th level. Fifth level drilling enabled the further exploration
of an ore pipe between 5th and 6th levels, while a number of holes
were drilled to investigate for possible ore adjacent to #4 dike.

Other exploration included some dog drifting north on the -160 sub which showed a sizable ore body. Exploration openings on -675 sub and the -700 sub will enable future drilling which should indicate more reserves.

74.00 X-Out was important in establishing important contacts which should facilitate working out the structure with more assurance.

h. Mather Mine "B" Shaft – An extensive diamond drilling campaign was conducted during the year. The holes were planned to cover three major objectives: these were: (1) the outlining of ore available to a 5th level, (2) detailing the ore outlines for 6th level mining, (3) outlining the 7th level ore bodies. Just prior to the end of the year, one diamond drill hole was started to explore for 8th level.

5th Level - Twelve holes were drilled to test for extensions of ore up the dip for a 5th level. Six of these holes encountered sizable runs of high sulphur ore at or above 5th level elevation.

6th Level - Twenty-two holes were drilled from 6th level and the sublevels above to detail the outlines of ore bodies which might be available for 6th level mining. This extensive use of diamond drilling allowed greater use of the limited number of mining crews for development and production work rather than for exploration by small drifts and small raises. This drilling increased slightly the ore reserves indicated in this area.

7th level - The 7th level exploration program included seven holes drilled down from the 6th level, and eight holes from 7th level workings. The results of this drilling indicate (1) large tonnages will be available to 7th level, (2) the ore will be standard grade, (3) the geologic structure is complex and further exploration will be necessary.

8th Level - Hole #72 was started down from the 7000 crosscut to explore for 8th level. Information from the 7000 crosscut and surface D.D.H. #136 indicate only a limited amount of height to the ore body above 8th level.

i. Makenese Mine - Geological plan maps were made of the Makenese Mine shaft at about 80 ft. intervals. The sinking was in graywacke, argillite and quartzite with some slate from about the -1100 to -1200 foot elevation.

j. Spies Mine - During 1951, an exploration campaign was conducted to explore that area south of the main level drifts to the Spies East ore body and north of the ore cut in surface holes #56, 59, 79, etc. For ease of exploration, it was decided to drill from underground due south to intercept any upfolding of the strata before the target was reached. Drilling was done from 4th and 6th levels and consisted of four holes which totaled 3362 ft. D.D.H. #56 drilled from 6th level, went 1050 ft. south on the 3200 E. Co-ordinate and as it was completely unoxidized cherty carbonate iron-formation, the upfolding was not oxidized and the iron-formation to
the south (D.D.H. #79 etc.) will be explored by drilling from surface.

Drifting on 8th level disclosed a considerable length of oxidized iron-formation which was unknown on the upper levels and will be explored laterally and in depth by drilling.

VII. LAND OFFERS AND OUTSIDE EXPLORATIONS

A. Land Offers

During the year 1951 the Geological Department continued to process the various Land Offers submitted to the Company. These comprised numbers 2621, 2622, 2625 to 2632, 2634 to 2659, 2661 to 2779, 2786, 2805 and 3002, all inclusive. The offers were divided into five general groups as follows:

<table>
<thead>
<tr>
<th>Area</th>
<th>No.</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Michigan</td>
<td>94</td>
<td>57.3 %</td>
</tr>
<tr>
<td>2. Minnesota</td>
<td>20</td>
<td>12.2 %</td>
</tr>
<tr>
<td>3. Canada</td>
<td>32</td>
<td>19.5 %</td>
</tr>
<tr>
<td>4. United States, other than Michigan or Minnesota</td>
<td>12</td>
<td>7.3 %</td>
</tr>
<tr>
<td>5. South and Central America</td>
<td>6</td>
<td>3.7 %</td>
</tr>
<tr>
<td>TOTAL</td>
<td>164</td>
<td>100.0 %</td>
</tr>
</tbody>
</table>

Under the long accustomed practice, the land offers include houses, etc., in addition to mineral lands. Thus, 60 of the 94 land offers in Michigan were for houses and lots.

During 1951 a total of $7,841.43 was spent in investigation of all of the land offers. This is more than had been spent in previous years because of the increased number of offers. Figure 2 shows graphically the 1951 distribution compared with the last four years preceding 1951.

B. Outside Explorations

The term "Outside Exploration" has been used for years to cover investigations and reports on exploration and exploitation projects by individuals or companies in areas in which we are interested. It provides a convenient method of referring to them and also for handling expenses incidental to these reports. The system was more or less inactive for a few years and was revived in 1951. Thus, the number processed in 1951 is not a good index to judge by. We did process a total of 46 in 1951. Figure 3 shows the relative distribution of the Outside Explorations. It is interesting to note that several of these became Land Offers during the year. We spent a total of $5,041.72 on all of the Outside Explorations.
Figure 2

GRAPH SHOWING RATE OF
LAND OFFERS

1946–1951, Inclusive

[Diagram showing bar graph with data for Michigan, Minnesota, Canada, United States, Michigan & Minnesota, South America, and additional bars for specific years and numbers.]
Figure 3

GRAPH SHOWING RATE OF
OUTSIDE EXPLORATIONS
1946-1951, Inclusive
Figure 4

LAND OFFERS and OUTSIDE EXPLORATIONS

1946—1951, Inclusive
VIII. OTHER DEPARTMENTAL HIGHLIGHTS

This portion of the Annual Report touches on the highlights of new developments, studies and projects not discussed in the preceding pages.

A. The Halliburton Reel

The Halliburton Reel, a wire line diamond drill hole testing unit, was purchased to augment our surveying equipment. The rated capacity of the unit is 6000 feet. However, the greatest amount of success has been realized in testing surface holes less than 2000 feet deep. It is conservatively estimated that the testing time has been reduced by 50%, where the unit can be utilized.

The unit is composed of a Wisconsin air-cooled engine driving a miniature hoist. The wire line passes through a depth-measuring device or odometer. For ease of handling and mobility the unit was enclosed in a trailer. Figure 5 shows the assembly in operation.

B. The Trailer Mounted Drill

For several years the Department has worked with the E. J. Longyear Company of Minneapolis to develop a mobile, self-contained diamond core on a trailer mounting. The completed unit was delivered and placed in service during the year. Figure 6 shows the rig in service. It affords a self-erecting mast capable of drilling an inclined drill hole from -30° to vertical. The unit has its own fluid pump (clear water or mud), shelter and tool house, rod racks and lighting plant. Initially, it has been equipped with a twin hydraulic swivelhead with fully automatic chuck and kelly drive. It is anticipated that the unit will provide another valuable adjunct to our drilling equipment.

C. Experiments in Mud Drilling and Related Sampling

During the summer and early fall of 1951, two series of drilling experiments were made independent of the regular drilling programs. These tests were made with a twofold purpose:

1. To determine the adaptability of the mud drilling procedure toward the more efficient drilling of unconsolidated material encountered in our drilling with a possible application to the drilling of overburden.

2. To experiment with sampling techniques to determine the possibility of using cuttings from a tricone type of bit for analyses of the material drilled.

First Series Tests (With Aquagel)

In the first series of tests, the Department's new trailer-mounted drill rig was used in conjunction with a "Shale Shaker" vibrating screen (See Figure 6). The tests were carried out on the Mather Mine "B" Shaft stockpile, and one hole 26 ½ feet was drilled.
Aquagel was used as the mud body and was passed through a 10 mesh screen at which point the +10 mesh size particles were removed from the fluid and kept as samples. Relative mud viscosity was kept at about 50. Drilling speeds were on the order of one foot per minute.

The hole kept open very well. After lifting the bit 24 feet in the hole, it was possible to lower it again with no difficulty.

Analyses were made of the samples obtained. Results were studied of material that had been washed only once and that which had been subjected to multiple washings. As a basis of checking results of the samples, analyses were compared with analyses of the stockpile made by Mr. Bennett, Chief Sampler.

In checking with Mr. Bennett’s results to duplicate his particle size of his sample fraction, the screened -8+20 mesh portion was used. The sample from the mud drilling of that size checked to within 0.22% Fe. of Mr. Bennett’s analysis. It also checked to within 0.09% Fe. of his composite analysis of the stockpile.

Although the tests were very limited in number, it showed that the aquagel mud may be expected to hold up the walls of holes in unconsolidated materials, the success of which, of course, will be inversely proportioned to the depth of the hole and friability of the material drilled.

The sampling and treatment of samples has indicated a very satisfactory procedure, and it appears to point toward the necessity of washing the sample only once to remove the aquagel sufficiently to give the required accuracy of analysis.

Second Series of Tests

The second series of tests were conducted to determine the possibility of the application of a starch base mud to a drilling circuit using a tricone bit and shale shaker and to determine the techniques required to obtain accurate analyses of the material drilled using the drill cuttings.

Tests were made on the starch to learn about its physical characteristics applicable to its utilization in our particular problems. A drill machine was set up and used to drill a prepared 10 foot broken ore section in a 16" diameter ventilation pipe.

It was found that to mix the starch in water, the most adaptable method was merely recycling the mixture in the pump circuit. Fermentation tests on the starch mixture were made over a two week period, at which time, the experiment was discontinued. The starch mud could be mixed with commercial preservative, in the proportion of 55 gallons to 1 pound, and at the end of that time was not noticeably broken down chemically. The temperature during the two week period varied between 60 and 80° F.
A Link-Belt shale shaker was used to separate the cuttings from the mud circuit. These cuttings were used to sample the material drilled. The separation was made by a 20 mesh screen.

The analyses of the samples showed that the starch adhering to the particles, produced deviation of not greater than 0.5% Fe. In the report from the Chemistry Laboratory, it is stated that "no large error, due to oxidation of starch by potassium permanganate, would result if the amount of starch was moderate." In the analysis of the cuttings it was found that the starch content, without washing, was about 4%. Mr. Owen Hassett, of the analytical laboratory, feels that the iron analyses, with the 4% pollution with starch, can still be kept within 0.3 to 0.4% of the actual iron content.

D. Cementing of Surface Drill Holes

Cementing of surface diamond drill holes falls into two major requirements; cementing of hole to condition the hole for safe drilling practices and cementing of diamond drill holes to prevent the flow of surface and underground waters into mining areas.

Deep hole cementing for purposes of good drilling conditions has been very successful by careful observance of volumes and speed of cementing of operation. It is next to impossible to cement a hole successfully where there is fluid motion in the hole.

Cementing of surface drill holes above or near a mining area is limited to paper tube or sectional cementing. In order to attain and be reasonably certain that a solid cement plug is present from bottom of hole to surface, the cement level must be checked regularly by means of drill rods. In a grouting technique it is next to impossible to predict the bottom of the cement plug, and, in many cases, this method may not prevent fluid motion in the hole.

E. Comparison of Drill Hole Deviation

Diamond drill hole deviation has been a very serious problem in the exploration for deep direct shipping ores. The targets, in general, are relatively small and therefore require the maximum accuracy in the directional drilling.

In the face of higher diamond cost and slower rate of drilling the department went to drilling the deep holes DX size (3 inch). In the final analysis, cost sheets disproved the fear of higher drill hole costs.

The following tabulation bears out the statement of less deviation with larger sized diamond drill holes. It is hoped that the problem can be further alleviated through changes in equipment and personnel education.
<table>
<thead>
<tr>
<th>Hole No.</th>
<th>Location</th>
<th>Horizontal Departure from Vertical BX – Hole</th>
<th>Horizontal Departure from Vertical NX – Hole</th>
<th>Depth of Drilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Sec. 11, 47-27</td>
<td>230</td>
<td>---</td>
<td>3730</td>
</tr>
<tr>
<td>10</td>
<td>Sec. 11, 47-27</td>
<td>245</td>
<td>---</td>
<td>3751</td>
</tr>
<tr>
<td>11</td>
<td>Sec. 11, 47-27</td>
<td>None</td>
<td>---</td>
<td>3890</td>
</tr>
<tr>
<td>37</td>
<td>Sec. 4, 47-27</td>
<td>1145</td>
<td>---</td>
<td>4106</td>
</tr>
<tr>
<td>58</td>
<td>Sec. 9, 47-27</td>
<td>275</td>
<td>---</td>
<td>2359</td>
</tr>
<tr>
<td>3</td>
<td>Sec. 29, 47-26</td>
<td>1137</td>
<td>---</td>
<td>2037</td>
</tr>
<tr>
<td></td>
<td>Total BX Deflection</td>
<td>3032</td>
<td>Total BX Drilling</td>
<td>19,873</td>
</tr>
<tr>
<td>42</td>
<td>Sec. 4, 47-27</td>
<td>---</td>
<td>360</td>
<td>2840</td>
</tr>
<tr>
<td>43</td>
<td>Sec. 4, 47-27</td>
<td>---</td>
<td>600</td>
<td>3700</td>
</tr>
<tr>
<td>12</td>
<td>Sec. 11, 47-27</td>
<td>---</td>
<td>25</td>
<td>3846</td>
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<td>Sec. 11, 47-27</td>
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<td>None</td>
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<td>14</td>
<td>Sec. 11, 47-27</td>
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<td>None</td>
<td>4338</td>
</tr>
<tr>
<td>19</td>
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<td>---</td>
<td>None</td>
<td>3664</td>
</tr>
<tr>
<td>20</td>
<td>Sec. 11, 47-27</td>
<td>---</td>
<td>25</td>
<td>2489</td>
</tr>
<tr>
<td>21</td>
<td>Sec. 11, 47-27</td>
<td>---</td>
<td>None</td>
<td>682</td>
</tr>
<tr>
<td></td>
<td>Total NX Deflection</td>
<td>1,010</td>
<td>Total 25,160 NX Drilling</td>
<td></td>
</tr>
</tbody>
</table>

F. Subsidence

The Geology Department with the Engineering Department continued their joint program of investigation of Mine Subsidence. The principal activity has been to study the changes on surface and underground together with geophone records in selected areas. The Engineering Department has made regular surveys of key stations. During the year this record was augmented with aerial photographs. Also, during the year, a system of 200 feet to the inch scale vertical cross-sections with full geological interpretations was inaugurated. Principal areas studied were:

1. Athens – Bunker Hill Mines
2. Mather Mine
3. Spies Mine
4. Cambria-Jackson Mine
5. Cliffs-Shaft Mine
View of Halliburton Reel in Operation for Testing Diamond Drill Hole Deviation
Figure 6

View of Trailer Mounted Diamond Drill Showing Drill, Mast, and Vibrating Screen for Collection of Samples