Memo No.	Subject
630	Progress Report - Upgrading of Flotation Concentrates by Combining Cleaner Flotation with the Regrind
631	Effect on Flotation of a Re-Use Water Containing Bentonite and Burned Limestone
632	Trip to Hibbing, Minnesota to Conduct Balling Tests with Specular Hematite Concentrate on Abe W. Mathews Novel Balling Device
633	Magnetic Circuit Flowsheet Development Tests - Ungava Bay Roasted Ore - O.E. 1136
634	Results of Duplex MOC Liberation Study on Coarse and Fine Grained Humboldt and Republic Ores
635	Heavy Liquid Study on Laboratory Flotation Concentrates from Republic Primary and Secondary Cyclone Underflows
636 (Supplement)	Land Offer 3716
637	Cross Checking of Standard MOC Results with Battelle Memorial Institute
638	Sample No. Mx-1374 - L.O. 3725
639	Quality Control Tests of Pellets from the Grate Discharge, Kiln Discharge and Cooler Product obtained during the Three-Day Test at Allis-Chalmers' Carrollville Pilot Plant using Eagle Mills Reground Concentrate
640	MOC Kiln at Domnarvet, Sweden
641	Fired Pellets Prepared in the Research Laboratory, Eagle Mills Pelletizing Plant, and Allis-Chalmers Pilot Plant for High Temperature Testing at Inland Steel
642	ACL Test Observations on Ungava Bay Concentrates
643	Car Top Sampling of Eagle Mills Pellet Shipments for Wheeling Steel Cargo July 5, 1958
644	Sample No. Mx-1379 - O.E. 1415-C
645	Sample No. Mx-1692 - L.O. 3726
646	Instrumentation for the ACL Pilot Plant
647	Progress Report for the Week Ending July 26th, 1958 - Pilot Plant Regrind Flotation Study
648	Observing Ore Boat Loading - "Benson Ford"
649	High Temperature Test Results of Pellets Indurated at the Research Laboratory, Eagle Mills, and at Allis-Chalmers
650	Progress Report for the Week Ending August 1st, 1958 Pilot Plant Regrind Flotation Study
651	Second Progress Report on Laboratory Regrind Flotation Studies
652	Progress Report for the Week Ending August 8, 1958, Pilot Plant Regrind Flotation Study
653	Sample No. Mx-1691 - O.E. 1233
654	Heavy Media Tests - Cliffs Shaft Crushed Stockpile Sample
655	Progress Report for the Week Ending August 15, 1958 - Pilot Plant Regrind Flotation Study
656	Complete Analyses, Humboldt Concentrates and Republic Pellets - 1957 Composites
657	Quality Control Tests of the Various Products of the ACL Test Conducted at Allis-Chalmers on March 26, 27, 28, 1958 - Material is Reground Humboldt Concentrate - 68 to 70% -325 Mesh
658	Progress Report for the Week Ending August 22nd, 1958 - Pilot Plant Regrind Flotation Study
659	Sample No. Mx-1694 - O.E. 1202
660 (Supplement)	Sample No. Mx-2007 - L.O. 3734
661	A Study of Some of the Heat and Material Flow Factors of the Domnarvet MOC Kiln
662	Microscopic Examination of a Sample Received from Stag Industries, Arizona
663	Some Comment and Discussion on Mineral Research Bureau's Report #36 and Supplement #1 Thereto

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Memo No.	Subject
664	Pictures Indicating Ring Formation in Lurgi Kiln Treating Humboldt Flotation Concentrate During Velocity Tests - June, 1958
665	Progress Report for the Week Ending August 29, 1958 - Pilot Plant Regrind Flotation Study
666	Observing Ore Boat Loading "James Norris"
667	Preliminary Downdraft Sintering Tests Utilizing Minus 3/8-Inch Brazilian Ore
668	Screening Efficiencies at 3/8" - Underground Ores
669	Improvement of Cliffs Group Ores by Screening Coarse Fractions
670	Progress Report for the Week Ending September 5, 1958 - Pilot Plant Regrind Flotation Study
671	Progress Report for the Week Ending September 12, 1958 - Pilot Plant Regrind Flotation Study
672	Quality Control Tests of Pellets from the Grate Discharge, Kiln Discharge, and Cooler Product obtained during the Four Day Test at Allis-Chalmers' Carrollville Pilot Plant using Humboldt and Republic Concentrates (4-21-58 through 4-24-58)
673	Some Effects of Particle Size and of Contact Time on the Reduction of Republic Crude Ore
674	Sample Nos. Mx-2008 - Mx-2017 - L.O. 3714
675	Sample Nos. Mx-2023 - Mx-2026 - L.O. 3736
676	Progress Report Republic Mill Test of Regrind and Reflotation Process Period: Start through Night Shift October 1st
677	Check Sampling Outside Iron Ores used in Cliffs Group Special Cargoes
678	Sample Nos. Mx-2018 - Mx-2020 - L.O. 3734
679	Sample Nos. Mx-2021 - Mx-2022 - L.O. 3741
680	Sample Nos. Mx-2028 - Mx-2031 - L.O. 3742
681	Progress on the Study of NH_4NO_3 as an Internal Oxidant and a Substance to Liberate CO_2 within an Agglomerate
682	Screen, Chemical Analysis and MOC Test Data for Republic and Tilden Crude Ores Shipped to Domnarvet, Sweden for Test in Kiln
683	Progress Report on Republic Regrind and Reflotation Test Second Period: Afternoon Shift October 1st through Night Shift October 7th, 1958
684 (Supplement)	Heavy Media Tests - Cliffs Shaft Mine
685	Progress Report on the Republic Mill Regrind Flotation Test for the Period October 8th through 15th
686	Results of Pilot Mill Regrind and Reflotation Tests on a Sample of Republic Primary Concentrate Aged for Increasing Time Intervals
687	Visit to Dominion Foundries and Steel Limited, Hamilton, Ontario
688	Observations of Royer Sand Separator and Blender and Discussion with Stanley Davies, President, Royer Foundry & Machine Company
689	Fourth Progress Report on Regrind and Reflotation Test at Republic Aging Study - October 15th through 21st
690	Correlation of Previous Agglomeration Tests at Allis-Chalmers Carrollville, Wisconsin Plant and Projection of Results to Large Commercial Units
691 (Supplement)	Laboratory Updraft Pelletizing Tests using Refloat Concentrate Produced in the Pilot Plant Flotation Circuit
692	Sample No. Mx-1933 - L.O. 3744
693	Updraft Pelletizing Process Using Fluid Coke from Hickman, Williams and Company as the Main Source of Fuel
694	Time-Temperature Study of Pellets Containing Various Additives

Continued - - -

Memo No.	Subject
695	Batch and Continuous Sintering Tests of Humboldt MOC Concentrate by the Lurgi Staff at their Testing Plant, Frankfurt/M, Germany, June 1958
696	Observing Ore Boat Loading - "Ascroft"
697 (Supplement)	The Effect of $CaCl_2$ on Pelletizing Hematite Concentrate
698	Proposed Test Program for Improving Specular Hematite Flotation
699	Structure & Chemical Analysis of Cliffs Shaft Lump Ore
700	MOC Tests of Humboldt and Republic Flotation Concentrate in the Lurgi Kiln, Frankfurt/Main; May 27-June 26, 1958
701	Preliminary Investigation of Variations in Standard MOC Test Results
702	Microscopic Examination of Drill Core Specimens from Junian County near Neceedah, Wisconsin - O.E. 1252
703	Land Offer 3276C
704	Preliminary Moisture Segregation Study of an Athens Stockpile Ore Sample in a Laboratory 25 Foot High Bin
705	Retesting of Groundhog River Surface Sample Composites, O.E. 1415-C
706	Meeting with Denver Equipment Company

Sample Shipments:

Each year various samples are shipped to laboratories and companies for test work. Presented below is a list of the samples shipped during 1958.

Date	Company	Amount & Samples	Purpose
1/6/58	Mr. F.C. Roberts Alhambra, California	85 Drill Specimens	For standard size thin sections
1/9/58	Mr. T.T. Quirke, University of Minnesota Minneapolis, Minnesota	38 polished specimens, Albanel and Sandspit	For research work
1/15/58	Fried-Krupp Essen, Germany	60 lbs. Humboldt rod mill feed	For reduction tests
1/15/58	Southwestern Engr. Company Los Angeles, California	50 lbs. Republic rod mill feed, 50 lbs. Humboldt rod mill feed	For flotation tests
1/15/58	A.P. Green Firebrick Co. Mexico, Missouri	16# Humboldt concentrate	Requested by Mr. S.K. Scovil
1/22/58	Mines Experiment Station University of Minnesota Minneapolis, Minnesota	1 bag, approximately 200# bentonite, 20 barrels approximately 20,000# MOC concentrates	For shaft furnace pelletizing tests
1/29/58	Battelle Memorial Institute Columbus, Ohio	Approx. 1,031# - 2 drums Class A, B1, B2 & C New Richmond	For basic test work
1/31/58	Institute of Mineral Research Houghton, Michigan	82-5 lb. boxes, 525# Albanel samples	For standard Davis magnetic tube tests
1/31/58	Pennsylvania Wire Glass Co. Philadelphia 3, Pa.	2 bags, approx. 38# Mather B Std. and Maas underground ores	For test work

Continued - - -

Date	Company	Amount & Sample	Purpose
2/4/58	Battelle Memorial Institute Columbus, Ohio	2-barrels, 924# Tilden Fire Tower Comp.	Test work
2/4/58	J&L Research Laboratory Negaunee, Michigan	1000# Republic Concentrate	Sintering tests
2/13/58	Kraft Chemical Company Chicago 8, Illinois	28# Maas special iron ore	For examination
2/18/58	Spencer Kellogg & Sons, Inc. Decatur, Illinois	5# reground iron ore concentrate	For agglomeration test work
3/3/58	Allis-Chalmers Mfg. Co.	67 barrels, 67,000# MOC concentrate	For ACL Process
3/3/58	Institute of Mineral Research Houghton, Michigan	12-5# boxes, 58# Isabella A-L Comps.	For standard MOC tests
3/4/58	Mr. T.T. Quirke, Jr. University of Minnesota Minneapolis, Minnesota	45 polished sections, Albanel & Sandspit 3-1/2 lbs.	For microscopic work
3/4/58	Allis-Chalmers Mfg. Co. Carrollville, Wisconsin	33 barrels, 29,700# MOC concentrates	For ACL Process
3/5/58	"	75 barrels Eagle Mills iron ore conc.	"
3/6/58	"	12 barrels Eagle Mills iron ore conc.	"
3/7/58	"	20 barrels, 20,000# Republic iron ore concentrate	"
3/14/58	Mr. E.L. Kirkwood, CCI Cleveland, Ohio	20 lbs. iron ore specimens	For display purposes
3/18/58	Allis-Chalmers Mfg. Co. Carrollville, Wisconsin	35,000#, 35 barrels Humboldt as is, 20 barrels Humboldt re-ground conc.	For ACL Process
3/19/58	Allis-Chalmers Mfg. Co. Carrollville, Wisconsin	37,000#, 37 barrels Humboldt reground conc.	For ACL Process
3/20/58	"	37,000#, 37 barrels, Humboldt reground conc.	"
3/25/58	Mr. H. J. Leach CCI Hibbing, Minnesota	100 ore specimens	For B-I-E
3/25/58	Mr. T.T. Quirke, Jr. University of Minnesota Minneapolis, Minnesota	41 polished specimens, 3#, Albanel, Project 17	For microscopic work

Continued - - -

Date	Company	Amount & Samples	Purpose
4/7/58	Pickands Mather & Co. Duluth 2, Minnesota	3 specimens Republic Mine crude ore, one polished section Republic ore, one tube Republic flotation concentrate, one tube Republic flotation pellets	For iron ore taxation hearing
4/8/58	U.S. Steel Corporation Monroeville, Pa.	3 tons (8 barrels) Humboldt iron ore concentrate	As per request of Mr. A. McAfee
4/11/58	Allis-Chalmers Mfg. Co. Carrollville, Wisconsin	68 barrels, 68,000# Republic regrind	For ACL Process
4/16/58	Michigan College of Mining and Technology, Houghton, Michigan	1 sample, Mx-444	For spectrographic analysis
4/23/58	Ford Motor Company Dearborn, Michigan	50# Humboldt crude, 50# Humboldt flotation pre-concentrate MOC calcine	For examination
4/25/58	Battelle Memorial Institute Columbus, Ohio	Approximately 5# New Richmond samples	For processing in the cross checking
5/6/58	Shell Oil Company Wood River, Illinois	2 bags, 125#, Eagle Mills filter cake	For agglomeration tests
5/20/58	Johnson-March Company Philadelphia 3, Pa.	5# Humboldt concentrate	Tests for dust control
5/22/58	Chem-Met Corp. Chicago 11, Illinois	33# Cliffs Shaft lump	As per request to Mr. A.R. Ham
6/19/58	International Minerals & Chemicals Corp. Mulberry, Florida	2 bags, 124# Specular hematite crude ore, Humboldt Mine	Test work
6/30/58	Mr. E.L. Kirkwood CCI Cleveland, Ohio	1 pkg. 2 samples, one Ohio Mine rejects, one Republic crude ore	For examination and display
7/2/58	Mr. D.M. Organist Petrographic Lab. Newark, Delaware	21 lab. pellets	For thin sections
8/11/58	Battelle Memorial Institute 505 King Avenue Columbus 1, Ohio	Products of D. tube separator, New Richmond B-1 & A	For correlation test work
8/15/58	Eutectic Welding Alloys Corp. 171-20 Station Road Flushing, New York	1 bag, 125# Humboldt flotation concentrate	Requested by Mr. A. McAfee
8/19/58	Denver Equipment Lab. 1755 Blake St. Denver, Colorado	1300#, 1 drum Republic concentrate filter cake	Requested by Denver Equipment for displays at Mining Congress

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Date	Company	Amount & Sample	Purpose
8/21/58	National Lead Company 2510 Crockett St. Houston, Texas	4 bags, 230# reground Eagle Mills concentrate	Requested by Mr. Miericke and Dr. McAtee of National Lead
8/26/58	Mr. Dreng Bjornaraa 2926 W. River Road Minneapolis, Minnesota	50# Republic specular hematite flotation Concentrate	For exhibit at Minnesota State Fair
9/12/58	Shell Oil Company P.O. Box 262 Wood River, Illinois	3 bags, 120# Ore Improvement fines, 65# Eagle Mills filter cake	For binder tests
9/18/58	Eutectic Welding Alloys Corp. 171-20 Station Road Flushing, New York	1 bag, 100# Humboldt concentrate	For examination and testing
9/26/58	Mr. Sven Eketorp Stora Kopparbergs A.B. Domnarvet, Sweden	1 pkg. 15# Tilden and Republic crude	For examination
10/3/58	Stora Kopparbergs Domnarvet, Sweden	58 drums Tilden crude, 60 drums Republic (R75) crude - Total gross wt. 46.2 tons	For MOC tests
10/8/58	Mr. Kenneth Merklin Pickands Mather & Company Hibbing, Minnesota	100 pieces of Republic crude ore	For Teachers Institute
10/9/58	McLouth Steel Trenton, Michigan	2 containers, 550# Pocket sample of Cliffs pellets	For examination
10/21/58	Mr. A.C. Behrendsen 462 East Franklin Liberty, Missouri	10# fired pellets-ACL process, 10# fired pellets, Updraft process at Eagle Mills Pellet Plant	For pellet tests
10/23/58	American Society for Metals, Russell Twp. Geauga County, Ohio	1 piece approx. 1000# jasper ore; 6 pieces of jasper ore and 6 pieces of iron formation	For ASTM Mineral Garden
11/18/58	Mr. P.L. Steffensen Bethlehem Steel Co. Lebanon, Pennsylvania	1 bag, 10-1/2# Republic concentrates	For firing tests
12/8/58	Mr. Jerome A. Schwartz 3520 Lake Shore Drive Chicago 13, Illinois	1 barrel, 128# Republic ore (R-75)	For testing
12/10/58	Dravo Corporation Neville Island Pittsburgh 25, Pa.	2-55 gal. drums, 1000# each Republic concentrate	For testing purposes
12/23/58	Denver Equipment Co. 1755 Blake Street Denver, Colorado	1 barrel, approx. 100# regrind flotation concentrate (R-93)	For settling tests

PART II

PYROLYSIS AND AGGLOMERATION

LABORATORY TESTS CONDUCTED TO STUDY VARIABLES AT THE PELLETIZING PLANT:

The following studies were conducted at the Research Laboratory and the Pelletizing Plant in an attempt to aid the process and/or operation of the Pellet Plant.

1. Correlation of the degree of regrinding and fired pellet production rate.

2. Effect of adding bentonite to process coal on the quality of the burn.

   (a) Effect of varying amount of bentonite
   (b) Effect on green pellet strengths

3. Study of the variability of green pellet size from the balling discs.

4. Study of the addition of process coal on the surface of green pellets.

   (a) Coal adherence versus green pellet size
   (b) Variance of quantity of coal on green pellets with time

5. Variables that affect bed permeability.

   (a) Various quantities of pellet sizes in pellet bed
   (b) Fines in pellet bed

6. Effect of changing flotation reagent from Oleic acid to Reagent 899.

7. Study of the quality of fired pellets in the hearth layer.

   (a) Magnetic susceptibility of grate discharge versus degree of induration
   (b) Carbon analysis versus size and quality of indurated pellets

8. Study of the efficiency of the screens on the grate discharge product.

   (a) Simplicity Double Deck Screen
   (b) Two types of screen cloths on top deck of Simplicity
   (c) Derrick Screen

9. Effect of water quenching versus air quenching on quality of fired pellets.

   (a) Severely quenching grate discharge
   (b) Normal quench received on product belt at Eagle Mills

10. Study of possible improvement in quality of fired pellets by tumbling pellets before sending them to stockpile.

11. Study of unpulverized Number 5 Buckwheat Coal as an alternate for pulverized anthracite process coal.

12. Suggested possible green pellet feeder for grate machine to minimize pellet breakage and deformation.

13. Rerolling and screening study on green pellets.

(a) Study at Eagle Mills on "B" Line
(b) Effect of rerolling on screen analysis and pellet strength
(c) Effect of pellet moisture on screenability
(d) Effect of retention time in reroll on pellet strength

14. Study on quality of fired pellets collected weekly for one year at Eagle Mills.

(a) Porosity
(b) Compression Strength
(c) Chemical Analysis

PELLETIZING TESTS AT ALLIS-CHALMERS CARROLLVILLE PILOT PLANT:

During 1958, a series of continuous pelletizing tests were conducted at the Carrollville, Wisconsin pilot plant of the Allis-Chalmers Manufacturing Company. The general object of these tests was to evaluate the grate-kiln-cooler system for Cleveland-Cliffs concentrates. Factors studied were the following:

1. Type of Concentrate.

(a) Laboratory Reground - Humboldt
(b) Laboratory Reground - Republic
(c) Eagle Mills Reground - Republic
(d) MOC Product - Pilot Plant

2. Concentrate Size Analysis

3. Green Ball Diameter

4. Kiln Temperature

5. Limestone Addition

6. Capacity

Samples from the grate, kiln, and cooler were returned to the Research Laboratory for quality control tests. Physical properties investigated were:

(a) Crushing Strength
(b) Abrasion Resistance
(c) Porosity
(d) True and Bulk Density
(e) Size Analysis
(f) Chemical Analysis

Research personnel also observed a test at Carrollville during which concentrates from Ungava Bay - magnetically converted - were pelletized and indurated.

With the known information gathered during the above listed tests, it was possible to project the approximate capacity and heat requirements to a large commercial-sized unit.

LABORATORY RESEARCH INVESTIGATIONS:

Numerous research projects were conducted at the Laboratory to investigate a widely varied series of programs. These programs originate both in the Laboratory and also from departments outside of research. These projects were as follows:

1. Binder Study

2. Standard balling and firing tests on refloated concentrate

   (a) Concentrate produced in laboratory pilot plant
   (b) Concentrate produced at Republic
   (c) Effect of limestone as an additive at different levels
   (d) Study of self-fluxing pellets

3. The effect of an internal oxidant upon the burning of coal in the interior of a pellet.

4. The effect of $CaCl_2$ to increase the surface tension of water and its effect upon pelletizing.

   (a) Effect upon green and dry strengths
   (b) Effect on the spalling resistance of pellets (drying rate)

5. Time-temperature studies of hematite pellets brought up to indurating temperature quickly.

   (a) Effect of pellet diameter
   (b) Comparison of hematite and magnetite

6. Preliminary sintering study on Brazilian ore for Colorado Fuel & Iron Company through Cliffs Sales Department.

   (a) Effect of Labrador ore in sinter mix
   (b) Dolomite necessary to produce self-fluxing sinter

7. Equipment to investigate the elevated temperature properties of agglomerates was purchased and partially assembled during the year.

8. Standard balling tests for Eagle Mills bentonite.

   (a) Carload Samples
   (b) Comparison of suppliers as to quality

ORE IMPROVEMENT PLANT STUDIES:

Two studies were conducted with material from the Ore Improvement Plant to (1) determine the resistance to spalling of the agglomerates formed within the Hardinge dryer and (2) to try and improve the structure and handling characteristics of the Group I fines.

Factors investigated under (2) above are:

(a) Balling Tests
(b) Flowability Tests
(c) Impact Resistance
(d) Additive Study
(e) Moisture Segregation
(f) Stockpile Drying

BALLING STUDY:

Balling tests were conducted at Eagle Mills utilizing "A" Line disc in closed circuit with a 4'x12' Allis-Chalmers Aero-Vibre screen. Variables studied were:

1. Capacity

2. Pellet quality and size

3. Effect of dry coal as a moisture adsorber on the surface of pellets

4. Effect of varying the location of the coal addition prior to rerolling

5. Types of concentrate

   (a) Regular Republic
   (b) Refloated Republic

Additional tests with a 9'x30' balling drum are continuing into the future.

MISCELLANEOUS TEST PROGRAMS:

The following test programs were also conducted during the year.

1. Evaluate the possibility of replacing anthracite coal at Eagle Mills with fluid coke from William Hickman & Company.

2. Observation of Abe Mathew's novel balling device -- shaped conveyor belt.

3. Discussion with Lurgi people on use of a Lurgi pellet hardening system and discussion with Mr. P.L. Stephenson regarding the use of a shaft furnace for indurating hematite pellets.

4. Evaluation of a Royer Sand Separator and Blender for sizing wet, run of mine ore.

5. Evaluation of high temperature pellet properties.

   (a) Tests conducted at Inland Steel's Woodmar Laboratory

      I. Effect of Pellet Diameter
      II. Method of Induration

6. Observations of shaft furnace pelletizing tests at the Mines Experiment Station, University of Minnesota. Material used was MOC concentrate.

7. Compute chemical analysis of pellets which will be produced from different properties in the future.

PART III

RESEARCH AND DEVELOPMENT WORK AND FLOTATION PROJECTS

DRILL CORE TESTING:

Drill core from the following drill holes in the several districts were subjected to standard metallurgical tests either grinding-magnetic concentration or MOC-magnetic concentration. Because of the work load at the Laboratory, some of this routine metallurgical testing was done, as in previous years, at the Institute of Mineral Research, Houghton, Michigan.

Property	Drill Hole Nos.	Location
Cascade	1,2	Section 29, T47N-R26W
Empire	35,36	Section 19, T47N-R26W
Isabella	5,6,7,8	Section 29, T47N-R26W
Isabella	4	Section 32, T47N-R26W
Ogden	1,2	Section 13, T47N-R27W
Ogden	3,4	Section 24, T47N-R27W

Project 17 - Albanel:

Drill core from the various regions of the Albanel Area was subjected to grinding-magnetic concentration tests. This work was done both at the Laboratory and at the Institute of Mineral Research.

Sandspit and "B" Areas:

Grand composites of the Sandspit and "B" area drill core were built up for the respective areas based on the Geological Department's probable ore estimates. The testing on these composites involved:

1. Grinding and magnetic concentration.
2. Coarse cobbing at 10 mesh followed by grinding and magnetic-concentration.
3. Grinding energy estimates based on the results of Bond grindability tests.

DUPLEX MOC LABORATORY STUDIES:

Liberation-Coarse and Fine Grained Ores:

Differences in the Duplex MOC concentrate grade for coarse and fine-grained Humboldt and Republic ores were believed dependent on the liberation size. The following study was undertaken to establish what grade differences might be expected.

1. Making batches of flotation pre-concentrates from coarse and fine grained crudes.
2. Determining concentrate grade after cobbing of the calcine.

3. Determining the final concentrate grade as a function of the grind to:

(a) Ascertain the various grades at a uniform pelletizing grind (75% minus 325 mesh)
(b) Ascertain the grinds necessary in each case to make concentrates in all cases containing, for example, less than 2% silica

Mineral Liberation in MOC Calcining:

Because of the ease with which the duplex-MOC calcines were by even cobbing of the calcine upgraded to 68% plus iron, a brief study was initiated to see if any mineral liberation takes place in the calcining. Liberation in the calcining could be attributed to (1) decrepitation and (2) autogenous grinding.

Heavy liquid tests were run on preconcentrate (1) as is, (2) which had been heated through the MOC cycle but without reductant, (3) which was reduced in the usual manner, and (4) which was reduced in the usual manner but with grinding media in the MOC kiln.

NEW RICHMOND AND TILDEN FIRETOWER:

New Richmond and Tilden Firetower pit estimates were made in cooperation with the Geological Department using as a class A cutoff a less than 10% silica greater than 85% iron unit recovery MOC magnetic concentrate. Total footages of Class A, B, and C material were calculated.

Battelle Memorial Institute Study:

Using the above classifications, composites of each of the classes of New Richmond and Tilden Firetower drill core were sent to Battelle for a preconcentration-MOC-magnetic concentration study. The first phase of the study was to determine:

1. The feasibility of preconcentration at a coarse size by heavy media separation to reject a lean tailing and reduce the feed bulk to MOC.

2. With elimination of these leaner fractions, which of the various classes of ores would yield MOC concentrates of acceptable grade.

3. By combined sizing and heavy liquid studies, what degree of crushing was necessary to give suitable liberation for coarse size preconcentration.

Standard MOC-magnetic concentration procedures were comprehensively cross checked at the two laboratories.

Davis magnetic tube test results as obtained by seven metallurgical laboratories on ground MOC calcine were compared.

As a further outgrowth of this study, Davis tube pilot plant control test results were compared with those for the pilot plant with commercial size magnetic separators.

FATTY ACID FLOTATION STUDIES:

Fatty Acid Reagents:

Several samples of flotation reagents were submitted for batch test evaluations. The reagents can be roughly classified as follows:

1. Distilled tall oils of varying rosin acid contents.

2. Distilled tall oils from suppliers other than Hercules and Arizona Chemical.

3. Low cost crude fatty acid materials.

4. Fatty acid reagents tailored so as to possibly improve the flotation or reduce the reagent cost.

Modifiers in Fatty Acid Flotation:

1. Fuel oil premixed with the fatty acid was used as a "carrier" to aid in the dispersion of the fatty acid. The aim of these studies was to see if fatty acid requirements could be reduced.

2. A fatty acid emulsifier "Emigol" was tested in mixtures with fatty acid. Again, the aim was to see if a chemical emulsifier could be used to aid in fatty acid dispersion and thus reduce fatty acid reagent requirements.

Some 20 other emulsifiers have been tried in various combinations.

3. A colloidal silica product called Ludox was tried as a silica depressant to improve the flotation concentrate grade.

High Intensity Conditioning:

It was demonstrated that a highly intense mixing action during fatty acid reagentizing resulted in improved flotation concentrate grade and recovery. Studies in high intensity conditioning are being carried on to the pilot plant to get more realistic data on the power requirements.

Pellet Plant Waste Water in Flotation:

In an integrated flotation concentrator-pellet plant a certain amount of waste water from the pellet plant would be available as reuse water for the flotation plant. This waste water might contain some bentonite and burned lime so a short program was initiated to see if these constituents had any influence on the flotation if used in either the grinding or flotation makeup water.

Humboldt Natural Magnetite:

This flotation study was carried out to determine (a) the effect on flotation of a prior removal of natural magnetite, (b) overall metallurgy, and (c) reagent consumption. The study is outlined as follows:

1. Installation on an experimental basis of a commercial size single drum cobber treating a portion of the plant hydroscillator overflow.

2. Collection of magnetic separator feed and non-magnetic tailings samples for batch flotation tests from several different crude ore types.

3. Collection of the magnetic product from different crudes for pilot mill grinding and finishing magnetic separator tests.

Improvement in Fatty Acid Flotation:

In connection with present operation and proposed expansions, studies were outlined to improve the flotation as in the following lines:

1. Conditioning - high intensity carried out to pilot plant scale.

2. Effect of conditioning solids.

3. Temperature influence in crude ore flotation.

4. Reagent dispersion including chemical emulsifiers.

To illustrate the difference in floatability of the Republic primary and secondary cyclone overflows with respect to metallurgy and reagent cost, batch cycle tests were run at Republic with each as feed. The flotation concentrates were subjected to heavy liquid tests to point out differences in metallurgy and liberation characteristics.

MISCELLANEOUS FLOTATION PROCESSES:

Reagent 899 Study:

Sufficient quantities of 899 and fatty acid flotation concentrates were made on a batch scale for comparative balling studies.

Batch tests were run on Republic Mill primary and on secondary cyclone underflows to compare their floatabilities with 899 reagents.

Southwestern Engineering Process:

The Southwestern Engineering Company did a flotation study on composites of Humboldt and Republic rod mill feeds using their process which is outlined as follows: grinding mill conditioning with fatty acid collectors and modifying reagents followed by conditioning with depressants prior to each flotation stage.

Comparisons of the Southwestern Process with the 899 and the fatty acid methods were made at the Laboratory.

Amine Flotation Upgrading of Tilden MOC-Magnetic Concentrates:

Amine flotation tests were run on Tilden MOC-magnetic concentrates from a reference sample of drill core rejects representing the Tilden Firetower area.

1. The laboratory 3 drum separator was used to prepare flotation feeds.

2. In the latest work, a commercial size counter-current separator was used on a batchwise basis using the unit as an overflow tailings discharge unit.

Amine flotation tests were run to study:

1. The use of coco, tallow, and rosin amine collectors; also, mixtures of coco and tallow amines.

2. The effects of fuel oil additions.

3. Variations in the relative amounts of caustic soda and starch depressants.

REGRIND AND REFLOTATION PROCESS:

The laboratory study was originally initiated with the view of possible further upgrading of the reground concentrates. Regrinding is essential for pelletizing and any reflotation would take advantage of enhanced mineral liberation. The following procedure appeared to give satisfactory upgrading.

1. Regrinding the concentrate to about 75% minus 325 mesh.

2. Heating the reground pulp at 75% solids to 208°F with steam injection.

3. Diluting the heated pulp and subjecting it to 3 stages of cleaner flotation with the low grade first tailing rejected.

4. By making a lower grade primary concentrate at higher recovery, the small iron unit loss in reflotation could be justified.

An aging phenomenon of better reflotation recovery without serious grade loss for primary concentrates that had been aged was observed.

Batch reflotation studies were conducted on Republic and Humboldt Mill primary concentrates.

Pilot Plant Reflotation:

The batch test results were so encouraging as to warrant pilot plant testing on a continuous basis. Republic concentrates in stockpile at the Laboratory and fresh concentrates from pocket were run through the pilot mill. Factors that were studied are listed as:

1. Flowsheet - arrangement of cleaning stages, scavenging, disposition of cleaner tailings.
2. Flotation cells - feeding arrangements, cell types.
3. Conditioner - heat exchanger retention times.
4. Hot or cold flotation water.
5. Aging of the primary concentrate.
6. Crude ore type influence.

Satisfactory upgrading was obtained on a continuous basis. High grade reflotation concentrates were produced for laboratory balling studies.

After the plant test described below, further work was done in the pilot plant to:

1. Determine why the upgrading in the plant was not as high as that in the pilot plant.
2. Determine cell requirements and throughput rates on such bases as cell horsepower, cell area, and cell volume to be used in proposed reflotation in the expansions.
3. Investigate feeding the various stages by gravity or by pumping to see if either gave metallurgical advantages.
4. Study the possible means of heating the reground pulps.

Republic Mill Test Reflotation:

The pilot plant results were so attractive as to warrant a mill test to get some realistic figures as to the metallurgy that might be attained on a commercial basis. Also, the test was initiated to give some idea of the heating requirements involved as compared to theoretical calculations.

The reflotation flowsheet for the plant test was similar to that developed in the pilot plant work. It consisted of three stages of cleaning, scavenging of the first two cleaner tailings, cycling the scavenger concentrate to the head of the circulating with the 3rd cleaner tailings, and rejecting a low grade scavenger tailing.

The principal variables examined included:

1. Three crude ore types.
2. Affect of the amount of reagent used in the primary flotation.
3. Influence of conditioner heat exchanger retention time.
4. Influence of the consistency in the heating and the resultant conditioner temperature on the reflotation.
5. Denver versus Fagergren cells for reflotation.
6. Aging with a parallel study run in the pilot plant.
7. Throughput rates in the reflotation circuit.

MISCELLANEOUS PILOT PLANT TESTS:

Magnetic Concentration of Duplex MOC Calcine:

Humboldt and Republic duplex MOC calcine from the fluosolids pilot plant was concentrated in a magnetic separation circuit. High grade concentrates were sent to Allis-Chalmers for ACL pelletizing tests.

The concentration circuit consisted of magnetic cobbers, a ball mill in closed circuit with a cyclone placed ahead of the ball mill, magnetic finishers, thickening and filtration.

Humboldt Natural Magnetite:

A drum type magnetic separator was experimentally placed in the circuit at Humboldt treating a portion of the hydroscillator overflow. The purpose was to determine the amount of magnetic material that could be scalped from the different ore types.

About 30-55 gal. drums of this magnetite was run through a magnetic concentration pilot mill consisting of magnetic cobbers, either open or closed circuit grinding of the cobber concentrate, and then finishing magnetic separation.

Final concentrate grades for specific grinds were determined.

Energy requirements for open and for closed circuit grinding were ascertained.

Regrind Study on Republic and Humboldt Flotation Concentrates:

Open and various closed grinding circuits were tested on Republic and Humboldt flotation concentrates to determine if any particular regrind circuit would reduce the grinding energy consumption.

Also investigated was the question as to whether the particular regrind circuit used had any influence on the balling of the reground concentrate.

Tonnages of Republic and Humboldt concentrates reground in the pilot mill were shipped to Allis-Chalmers for ACL pelletizing tests.

Empire:

Empire ore from an outcrop sample was milled in a magnetic separation circuit consisting of coarse cobbing, two stages of ball milling in closed circuit, and magnetic finishing. The testing was limited by a change to the reflotation testing.

Republic Crude Ore Flotation:

Republic crude ore was milled in the flotation circuit for the several test programs to be eventually covered:

1. To prepare preconcentrate for the reflotation circuit so as to be able to test the complete flowsheet on a continuous or semi-continuous basis.

2. To improve the flotation of the Humboldt and Republic ores in such studies as:

(a) High intensity conditioning with the Fagergren turbine impellor
(b) To test on a continuous basis any aspects as developed in batch work such as the influence of temperature

J&L Aerofall Mill Test on Republic Ore:

Roughly 15 tons each of a coarse and a finer-grained Republic ore were ground to 48 mesh in an Aerofall Mill at the J&L Ores Research Laboratory. The purpose of this testing was:

1. To obtain grinding energy and steel consumption data.

2. To establish if the Aerofall ground feed gave flotation metallurgy superior to that of a conventional wet ground feed.

Comparisons of the relative floatabilities were made on a batch scale with a limited amount of Aerofall ground ore available for pilot mill comparisons.

PART IV

MICROSCOPY SECTION

SINTERING - LABORATORY INVESTIGATION OF SINTERED PRODUCTS PRODUCED FROM MATHER "B" AND ATHENS UNDERGROUND ORES AT THE MINES EXPERIMENT STATION:

The object was to determine (1) the occurrence, transformation, and distribution of minerals in the sintered products and (2) the texture and quality of the sintered products; and to attempt to explain why the test results were not encouraging.

The study revealed that raising Fe:SiO2 ratio has produced a reverse effect due to high temperature heating in an extremely reducing environment. It did not minimize slag constituents, on the contrary, the slag content reached nearly a maximum because of the formation of fayalite.

The increase of fuel caused a raise of temperature and changed the environment from reducing to a strongly reducing. This promoted the development of wustite and fayalite, and consequently decreases the reducibility of the sinter.

PELLETIZING:

Effects of Firing Time, Pellet Size and Additive Type on Pellet Quality Produced at 2500°F in a Laboratory Kiln:

The investigation results revealed that the pellets with bentonite and limestone are certainly superior to those with bentonite only; the strength of pellets fired in furnace more than 20 minutes is definitely stronger than those less than 20 minutes. Other factors being constant, the larger pellets usually revealed a higher percentage of micro-pores and a lower rate of grain growth as compared to the smaller ones.

Effects of Type and Quantity of Additives on Pellet Quality Produced at Approximately 2500°F by Updraft Firing:

Due to the variation in degree of induration, no positive conclusion can be reached in regard to the pellet quality among tests as a whole. However, the study does indicate that the type of additive is directly related to the pellet composition, structure, and texture. The facts are as follows:

1. The stability of minerals in the pellets at 2500°F is determined by the existing chemical environments, which is in turn governed by the type and quantity of additives used in the pellets.

2. The pellet strength is directly related to the space:solid ratio, and the types of spaces and solids in the pellets.

3. The bonding materials in the pellets with bentonite are mostly ore bridges; in those with limestone and bentonite are ore bridges and slags; and in those with internal coal are slags.

4. The updraft air in pelletizing practice usually produces pellets with non-uniform strength because of the uni-directional firing.

5. Coal appears to be less desirable for a fuel and as an additive in pelletizing.

Pellets Produced from MOC-Concentrate of the Humboldt Flotation Rougher Concentrate at Lurgi:

These pellets are characterized by concentric shelling and centripetal oxidation of magnetite to hematite. The pellet strength is essentially determined by the degree of recrystallization and the degree of centripetal oxidation. A qualified pellet may be obtained by recrystallization without oxidation but cannot be obtained by oxidation without recrystallization.

An Interpretation of Ash and Devolatilized Coal Fragments in Pellet Products from Eagle Mills Plant:

The presence of ash and devolatilized coal in pellets suggested the insufficient air supply during combustion. The air deficiency was attributed to the formation of an impervious fused pellet layer at the upper part of hearth layer during ignition, which directly caused a restriction of updraft air flow in the combustion zone. This, in turn, affected the degree of pellet induration and consequently the efficiency of pellet production may be reduced.

MOC-CONCENTRATION - MINERALOGICAL AND TEXTURAL TRANSFORMATION OF MICHIGAN LOW GRADE ORES AT HIGH TEMPERATURES UNDER VARIOUS CHEMICAL ENVIRONMENTS:

These tests were the first of a series comprising detailed research into all phases of the MOC process and in an attempt to duplicate the conditions which might exist in a reactor preheat zone.

The results of the investigation indicated that air at 1940°F and 1950°F could only oxidize magnetite to martite (hematite); coal at 1940°F theoretically should change both ore texture and mineralogy, but the effect appeared to be very little; and hydrogen and nitrogen at 1950°F could change both ore composition and ore texture.

MICHIGAN LOW GRADE ORES - MINERALOGICAL AND METALLURGICAL CHARACTERISTICS OF THE LOW GRADE ORES FROM NEW RICHMOND AND TILDEN AREAS:

The low grade ores from the New Richmond and Tilden areas have been intensively investigated respectively. It was concluded that the martite-chert is generally the most favorable material for MOC-concentration. The increase of goethite, ocherous hematite, and primary hematite in the ores will increase the amount of silica in the concentrates.

MICHIGAN HIGH GRADE ORES - A COMPARATIVE STUDY OF PHYSICAL CHARACTERISTICS OF THE DIRECT SHIPPING ORES FROM CASCADE DISTRICT AND THOSE FROM BUNKER HILL, MAAS, AND MATHER MINE "B" SHAFT:

This investigation covers the absorption, evaporation, and saturation tests accompanied with a microscopic examination.

It was concluded that the Cascade ore is essentially made up of more than 60% non-porous martite and less than 40% soft porous earthy hematite. Physically, it is a fairly hard porous and granular ore having a maximum moisture content of not more than 9%.

In comparison with the ores from the Bunker Hill, Maas, and Mather Mine "B" Shaft, it will yield a lower moisture content and probably give rise to an ore structure resembling the ore sample examined from the Maas Mine.

LAND OFFERS AND OUTSIDE EXPLORATIONS:

During the year, specimens and samples from three land offers and two outside explorations were studied. The purpose was to study the mineralogical composition, texture, and mineral associations in the specimens and samples and their effects on ore beneficiation.

MISCELLANEOUS:

Two screened samples of Jens Rhude's spheroid media, and one sample received from Stag Industries, Arizona were also microscopically studied.

PART V

FLUOSOLIDS REACTOR PILOT PLANT

During the year 1958, activity on the MOC (magnetic oxide conversion) front proceeded at a steady but reduced rate. The FluoSolids reactor was shut down in January of this year as a necessary economy measure and efforts were concentrated on completing two pilot plant test series using the Lurgi kiln for the processing of fine rougher flotation concentrates. A preliminary study of the Domnarvet, Sweden MOC kiln was completed and arrangements made for pilot plant tests of this unit early in 1959. Limited laboratory studies were made of the effects on metallurgical results of particle size, preheat and reduction temperatures. Additional laboratory test series are in process delineating the range of experimental variation inherent in standardized test procedures.

The pilot plant test work with the FluoSolids reactor was incomplete but the results obtained indicated that, with some necessary redesign, the reactor will serve satisfactorily for the reduction of rougher flotation concentrates. The work on crude ore was not completed, but indicated that proper choice of temperatures was probably a factor in the final production of a low silica magnetic concentrate.

Pilot plant tests of the Lurgi kiln at Frankfurt/M, Germany showed this device to be unsatisfactory for the treatment of fine concentrates because of the difficulty in keeping the fine material in the kiln. Indications were that if the concentrate could be retained in the kiln, then the metallurgical outcome would be satisfactory. Various devices were tried as means of reducing the dust carryout at operating gas velocities. Acceptance of a 120% circulating load on the kiln through hot cyclone dust collectors made the pilot plant kiln operable, however, it is felt that such a solution is not a practical one for a large-scale operation. Limited tests made in previous years indicate that the Lurgi kiln could be used to treat coarse crude ore satisfactorily.

For greater process success regardless of the vessel used for the MOC reaction, it is desirable that the heat requirement be less than that predicated for either the Lurgi kiln or the FluoSolids reactor. A kiln developed at Domnarvet, Sweden contains an integral heat exchange section and offers possible improved process

heat economy. This kiln has been viewed by several CCI people and plans have been completed for testing fine concentrate (minus 48 mesh) and crude ore (minus 6 mesh) in this unit early in 1959. We now know that the Lurgi kiln will treat coarse (1/2") crude ore satisfactorily and that the Dorr FluoSolids reactor will handle fine rougher flotation concentrates effectively, hence, once the relatively efficiency of the Domnarvet kiln has been assessed, numerous combinations can be calculated to point to the most effective device for the MOC process.

PART VI

CHECK SAMPLING PROGRAM

Early in 1958, a quality control program was conducted at the Mather Mine "A" and "B" Shafts and at the Bunker-Hill Mine on ores being stockpiled. The purpose of the program was to collect underground ore samples for qualityand screening tests during the winter stocking season.

During the 1958 season, a number of outside ore shipments from the North Range Mining Company were check sampled at the request of the Ore Grading Department.

A number of ore boat loadings were observed at the Marquette and Escanaba ore docks at the request of the Ore Grading and Ore Sales Departments.

A visit was made to the Dominion Foundries and Steel Company (Dofasco) Hamilton, Ontario at the request of the Ore Sales Department. The purpose of the visit was to observe ore boat unloading and to observe Lower Lakes Chemists boat sampling procedures.

Ore samples were collected from mine pocket and stockpile shipments during the 1958 season for general sampling correlation data and structure tests.

A number of ore and coal samples were collected for special tests during the year.

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PART VII

RESEARCH PILOT PLANT

During 1958, approval was received to proceed with engineering and construction of a new research pilot plant to augment the research facilities of the Metallurgical Department. The proposed plant would encompass all phases of concentration on a pilot scale and also include pilot facilities for pyrometallurgical studies of magnetic oxide conversion and agglomeration by sintering and pelletizing.

Preliminary design of the new pilot research facilities began early in 1958. Abe Mathews Engineering Company of Hibbing, Minnesota was contracted to furnish preliminary design plans and specifications of the pilot unit.

The plant is located in the E 1/2 of NW 1/4 of Section 36, T48N-R26W, Marquette County and approximately 900 feet north of the Eagle Mills Pelletizing Plant. The physical dimensions of the plant are 60' wide by 200 feet long and it is divided into a concentrating section and a pyrometallurgical section.

Construction of the Research Pilot Plant began in May, 1958. The Cleveland-Cliffs Iron Company acted in the capacity of prime contractors, letting out the various phases of construction and erection by bid. The following are a list of contractors directly involved in the construction of the Pilot Plant.

A.W. Mathews - Engineering & Design
Pajula & Maki - Excavation & Foundation Work
Proksch Construction Company - Water Supply Line
Worden Allen Company - Structural Steel Fabrication and Erection
Elwin G. Smith - Siding and Insulation
Markell Supply Company - Roofing and Ventilators
A.W. Mathews Engineering Co. - Machinery Erection
Kielinen & Son - Interior Finishing
Cloverland Contracting Co. - Piping, Plumbing and Heating
Brandt & Nielson - Painting
Minneapolis-Honeywell - Instrument Installation

Anticipated completion of the Research Pilot Plant is February, 1959. Upon startup, primary interest will be focused on pelletizing of fine ore concentrates embracing the grate-kiln system proposed by the Allis-Chalmers Manufacturing Company.

The concentrating section of the new plant is tentatively expected to be operating in April or May of 1959. The flowschemes used will be versatile in that all pilot equipment will be of a portable nature.

ELECTRIC POWER DEPARTMENT
ANNUAL REPORT
YEAR 1958

Electric energy produced in the generating facilities of The Cleveland-Cliffs Iron Company during the year 1958 amounted to 133,308,919 kwh. This was a decrease of 30.8% below that which was generated during the year 1957. Of this amount generated 114,960,849 kwh were billed directly by our Company and were used as follows: The Cleveland-Cliffs Iron Company used 25,218,630 kwh (18.9%); The Athens Iron Mining Company used 1,352,981 kwh (1.0%); The Negaunee Mine Company used 30,503,709 kwh (22.9%); The Marquette Iron Mining Company used 45,586,033 kwh (34.3%); The Humboldt Mining Company used 3,201,736 kwh (2.4%); and the Upper Peninsula Power Company used 9,097,760 kwh (6.8%). Of the energy produced by Cliffs production facilities 64.2% was produced in our hydroelectric stations, 6% in the Ishpeming Steam Station, 0.8% in the Ishpeming Diesel Station, and 29% in the Presque Isle Station of the Upper Peninsula Generating Company.

In addition to the 9,097,760 kwh (6.8%) billed from our Company to Upper Peninsula Power Company 18,348,070 kwh (13.7%) were delivered to that company by the Upper Peninsula Generating Company, and billed for our account by the Generating Company to the user in accordance with mutual agreements. Of the amount which was supplied to the Upper Peninsula Power Company by our Company's wholly owned generating facilities 88% was supplied by the Ishpeming Steam Station and 12% by the Ishpeming Diesel Plant.

Our Company and the companies operated by it used 105,863,089 kwh, which was a decrease of 19.4% below the amount used for these operations during 1957. Energy supplied to The Cleveland-Cliffs Iron Company (including that delivered to the Athens Iron Mining Company) was obtained entirely from hydroelectric plants. The Negaunee Mine Company, Marquette Iron Mining Company, and Humboldt Mining Company obtained 74.4% of the energy used by them from the hydroelectric facilities, and 25.6% from the Upper Peninsula Generating Company's Presque Isle Plant.

Several conditions arose during this year which influenced the cost of energy production in our generating facilities and which resulted in increases in cost of energy to the consumers served by our generating plants. During 1957 and for the first three months of this year the Upper Peninsula Power Company was obtaining a large portion of the energy required on the old Cliffs Power and Light Company transmission and distribution facilities, as well as a substantial amount of energy which was being transmitted to the Houghton area, from the Ishpeming Steam Station, the Ishpeming Diesel Station, and from our portion of the energy generated by the Presque Isle Plant of the Upper Peninsula Generating Company. Operation of a new generating station in Escanaba by the Power Company began early in February and as the utilization of this new generating station progressed a greater quantity of energy was obtained from it and a lesser amount was obtained from our generating facilities. During 1957 our Company delivered to the Upper Peninsula Power Company a total of 61,811,739 kwh and during 1958 the quantity of energy delivered was reduced to 27,445,830 kwh - a total reduction of 55.5%. Since the Upper Peninsula Power Company paid to our Company a portion of our fixed charges and of our administrative and general expense based on the amount of energy received, the reduction in the amount of this expense carried by them during 1958, below that which was carried in 1957, exceeded $104,000. The reduction in the fixed charges and the administrative and general expense carried by the Upper Peninsula Power Company resulted in an increase in cost, above that offset by the minimum deficiency provisions in our agreement, of approximately 8/10 of a mill per kwh to our Company and the companies operated by it. In addition, the compensation

No.-T5203 WIRE BOUND
No.—5203 PADDED

	(1) Kwh	(2) %	Kw. Input	
G. L. & P. Co.	25218630	21.9	18.9	1
Athens	1352981	1.2	1.0	2
Keystone	30503709	26.5	22.9	3
Marquette	45586083	39.7	34.3	4
Humboldt	3201736	2.8	2.4	5
U. P. Power Co.	9097760	7.9	6.8	6
Total	114960849	100	86.3	7
				8
Hydro	85542459	74.4	64.2	9
Steaming Plant	7991085	6.9	6.	10
" Diesel	1106675	1.0	0.8	11
Bergen Sta.	20370630	17.7	29.0	12
	114960849	100.	100	13
				14
				15
				16
				17
				18
				19
				20

paid by the Power Company to our Company for the use of our generating facilities dropped by approximately $50,000 to $17,888.

In addition to the fact that the proportion of the generating expense borne by the Upper Peninsula Power Company was greatly reduced, The Cleveland-Cliffs Iron Company curtailed its operations in the early part of the year and reduced the total amount of energy which it required from the generating facilities. The total reduction in the energy required by our Company and our affiliates amounted to approximately 25,000,000 kwh (19.3%).

The reduction in overall energy requirements by both our Company and the Upper Peninsula Power Company, coupled with increased carrying charges because of investments made to increase the capacity of the transmission system, resulted in an appreciable increase in wheeling charges which were charged by the Upper Peninsula Power Company to our Company. The total wheeling charge made by the Upper Peninsula Power Company increased approximately $50,000 above that which was charged during the past year. This was an increase of 31% and amounted to approximately one-half of a mill for each kwh utilized by our Company's operations. In spite of the reductions which were made in personnel and man hours worked during the year, the decrease in utilization of generating facilities, coupled with wage increases and increased wheeling charges, caused an increase in the cost of energy to both our Company and the companies operated by it. Energy required by The Cleveland-Cliffs Iron Company was delivered at a cost of $.0082 per kwh. This is an increase of approximately 31% above the energy cost in 1957 but was a reduction of 6% below the cost of energy in 1956. Similarly, the energy supplied to our affiliated companies during the past year increased above the previous year to $.0131, an increase of approximately 18% above the corresponding cost last year.

In spite of the increases in energy production costs and generating facilities idled by reduction in energy supplied to Upper Peninsula Power Company, to our Company and to the companies affiliated with it, we estimate that it would have cost The Cleveland-Cliffs Iron Company approximately $251,000.00 (120%), and the affiliated companies $261,374.00 (24.7%) more to have purchased their energy requirements at the utility rates prevailing in the area than was charged by the Power Department. The total of these savings in ore production costs is estimated at approximately $512,000.00 for the operation of our Company and the companies associated with us. In addition to the savings effected for these companies, the Power Department shows a net earning, after depreciation deductions, during the 12-month period from charges to the Upper Peninsula Power Company and to our Company's associates of $263,321.00.

Precipitation for the year 1958 was again below normal as had been expected, but was better than was experienced in 1957. During 1957 the total precipitation in Ishpeming was 24.53" compared to 30.81" during 1958. This increase in precipitation was reflected in the quantity of energy generated by the hydroelectric plants, which amounted to 85,542,459 kwh during 1958, compared to 80,657,336 kwh during 1957. It is hoped that the increase in precipitation during the past year is indicative of a trend towards better water conditions as a result of our having reached the low part of the dry cycle; however, precipitation during the fall and early winter has been below normal and the indications are that no better than an average water power year will exist during the coming year.

At the beginning of 1958 the plans for the installation of a second unit at the Presque Isle Power Plant of the Upper Peninsula Generating Company had been definitely postponed and all engineering work on this unit had been stopped, with the idea that the unit would not be necessary until early in 1962. However, there existed at that time a contract with the General Electric Company for the purchase of a turbo electric generator and other electrical equipment for the plant, to be delivered early in 1959. Although this agreement contained appreciable advantages

in price, to have accepted delivery as scheduled would have involved a premature investment and storage expense for a minimum of two years. These expenses offset the advantages to be gained and the contract was renegotiated with the supplier during January. The revised contract provides for the purchase of this equipment to be delivered some time during the year 1961, so that the plant can be constructed and placed in operation early in 1962. Any cancellation charges or other similar charges, which were caused by the placing of the previous order, will be held in abeyance until the second unit is purchased and delivered. This matter has been reviewed recently and the indications at present are that both our Company and the Upper Peninsula Power Company will have sufficient power generating equipment to take care of the expected power requirements until 1962. These plans will be reviewed from time to time in view of future developments.

Pending at the beginning of the year was the consideration by our Company and the Power Company of the revision of the basic agreement between us. It had been considered necessary to revise this contract primarily on account of the need for changes necessary to provide for the installation of the second unit at the Upper Peninsula Generating Company's Presque Isle Plant, and to remove several inequities which the contracting parties considered existing in the present agreement. A considerable amount of work had been done on the form of the revised contract but when the expansion of the Presque Isle Plant was postponed it was decided by both companies that it would be desirable to postpone the revision of the basic agreement in order that data could be gathered which could be used to determine the effect of the proposed contract on both companies. This matter was agreed upon early in the year and the compilation of the necessary data was started in March. The data on system demands, energy utilization, power generation and other pertinent information is being assembled by the Electric Power Department, and the expense incurred by this work is divided between our Company and the Power Company. It is felt that this information will provide a much sounder basis for approach to the revision of the contract than would have been available otherwise. As a temporary expedient several inequities which it was felt existed in the present agreement have been settled on a temporary basis.

At the beginning of the year there existed a disagreement between our Company and the Power Company regarding the minimum bill for which the Power Company was responsible. The basic agreement provided that this minimum bill should not be based on any period during which abnormally low water conditions existed. It was the Power Company's contention that abnormal water conditions had been in existence throughout 1957 and, therefore, that no minimum bills should be payable during 1958. It was our Company's feeling that though water conditions were low they were not sufficiently below normal to justify complete waiving of the minimum bill charge. A compromise was reached on this matter in which the Power Company agreed to pay minimum bills in amount of 50% of the full amount stipulated by the contract, and in so doing to waive its claim of abnormal water conditions. At the same time several other minor points of disagreement or ambiguity in the contract were agreed upon.

Later in the year it became evident that the supply of energy to the Ishpeming area, where used by the Power Company, could be made more economically from the newly constructed Escanaba Steam Generating Plant of the Power Company than from the Presque Isle Generating Station if the Power Company was required to pay fixed costs for the energy which it used from Presque Isle above that to which it was entitled by its 50% ownership. Supply of this energy from the Escanaba Steam Station tended to increase the unit production cost of energy in the Presque Isle Station and deprived our Company of relief which might be obtained by it from having the Power Company defraying a portion of our fixed costs at the Station. Accordingly, an agreement was reached in the latter part of the year with the Power Company which would enable it to obtain energy for the Ishpeming area from

the Presque Isle Power Station by operating that Station at as near full load as was practical, and providing for the payment by the Power Company of a portion of our Company's fixed charge. The amount to be paid for such energy was so fixed that it would result in no increase in the cost of energy delivered to the Ishpeming area, but would provide for partial relief of the Generating Company's fixed charges being paid by our Company. This agreement was reached to be effective with the energy delivered during the month of October, and is to continue until revoked by either party.

The Upper Peninsula Generating Company's Presque Isle Plant delivered 115,168,700 kwh to the transmission system last year. This was a reduction of approximately 25% below the capacity production which was delivered during 1957. Of this energy 20,320,630 kwh were delivered to our Company and the remainder, 94,848,070 kwh, were delivered to the Upper Peninsula Power Company. Of this latter amount 76,500,000 kwh represented the quantity of energy to which they were entitled by their half ownership in the plant and the remainder of 18,348,070 kwh represented the amount which was delivered to them from our Company's portion of the generating station ownership. The cost of energy to our Company from this plant during 1958 amounted to $.0135 compared to a cost of $.0076 in 1957. This high cost during 1958 was due mainly to increased fixed costs per kwh caused by our Company utilizing only 50% of the energy to which it was entitled, 26% being for use in its own operations and 24% being resold to the Upper Peninsula Power Company.

The Presque Isle Plant was shut down for inspection and overhaul on April 12 and remained out of service until April 27. During this period a complete inspection was made of all apparatus in the plant and the induced draft fan and pulverizers were overhauled. No bad conditions were found in the plant and no difficulty was experienced during the repair period. On August 3 a superheater tube in the boiler failed. Investigation showed that the failure was caused by a thin place in the tube which was the result of bending the tube at the time of manufacture. The bend was made in such a manner that the thickness of the tubewall was too drastically reduced. Investigation of several adjacent tubes was made but the same difficulty was not discovered in any of them. The tube which failed was repaired and the unit was returned to service on August 6. No other mechanical failures were experienced at this plant during the year.

The question of whether or not our Company should purchase the lessor's rights under the Dead River lease agreement between our Company and the Longyear Realty Corporation and the Groton Realty Corporation was under discussion at the beginning of the year. The lessors felt that income tax conditions might make it more profitable for them to invest their money in other securities than to continue as the lessors of the Dead River water power lands. Careful consideration was given to this matter by our Company, but a final decision was reached on April 9 that purchase of the rights under this agreement would not be advantageous to our Company at the price being considered by the other parties.

During 1957 contracts had been executed with the Marquette Iron Mining Company and the Negaunee Mine Company for delivery of power to them from the generating facilities of our Company. Contracts were executed during 1958 with the Humboldt Mining Company and the Athens Iron Mining Company. The Humboldt Mining Company, previous to reaching a power sales agreement with our Company, had been purchasing energy from the Upper Peninsula Power Company under their regularly filed schedule and our Company had been delivering this energy to the Upper Peninsula Power Company at the cost price of production. The difference between the production cost and the price at which the energy was sold by the Upper Peninsula Power Company was refunded to our Company and the amount thereof was taken into our Company's profit and loss. Execution of this new contract with

the Humboldt Mining Company will provide for a smaller profit on energy used by that company in the future. The Athens Iron Mining Company, on the other hand, has been purchasing energy for its operation direct from our Company at our Company's production cost. The new contract provides that energy used by that company will be purchased at the same price as that paid by the other partners in their operations, and this contract will result in a profit from the Athens Company which was not available prior to the execution of the contract.

In January, a faulty switching operation had caused the two hydroelectric generators at the McClure Plant to be closed on to the transmission system without proper synchronization. Early in February the No. 2 unit at the power plant developed excessive vibration. An erection engineer was obtained from the S. Morgan Smith Company, who manufactured the turbine, and extensive measures were taken in an attempt to eliminate the vibration. All of these attempts were unsuccessful until the unit was completely dismantled and all of the moving parts were taken to the Lake Shore Company's shops at Marquette, and all mechanical inaccuracies which existed in them were eliminated. After this was done and the complete generating unit was realigned, it was placed in operation on June 2. Satisfactory performance has been obtained since that time. On August 22 the same condition arose in the No. 1 unit at the plant. Since both of these units experienced the same trouble it is considered very probable that the previous switching accident was the cause of the difficulty. The experience with the No. 2 unit indicated that the cure for the improper operation consisted of correcting all mechanical inaccuracies and realigning the unit, so this procedure was followed with the result that it was possible to place the unit back in operation on October 13. Both units are now operating satisfactorily and it is considered that no further difficulties will be experienced.

On April 8 the Upper Peninsula Power Company had a ground-breaking ceremony for the John H. Warden Steam Generating Station, which is being constructed at the site of Celotex Corporation's new factory at L'Anse, Michigan. This power plant will supply both energy and processed steam at the Celotex Corporation for the operation of its wallboard factory, and will also provide a surplus of approximately 5,000 kw of electric energy capacity for use elsewhere on the Upper Peninsula Power Company's system. The new plant is expected to begin operation in August of 1959. It is connected directly to the Upper Peninsula Power Company's Houghton operations by transmission line and will supply energy to that area which is now being supplied by the operation of the Houghton Steam Electric Station and by energy received from the Ishpeming area over the interconnecting transmission line. The production cost of energy at this station will be the lowest on the transmission system because of the utilization of process steam by the manufacturing company and the availability of this low cost energy will adversely effect our Company's energy production costs because of the reduction in the utilization of the Presque Isle Generating Plant by the Power Company.

The Ishpeming Steam Electric Station operated during the first four months of this year. The total production during this period amounted to 7,991,085 kwh, which is less than half of the production capacity of this plant. The low quantity of energy generated was due to the light load conditions which prevailed and, also, due to the fact that the Escanaba Steam Generating Station of the Upper Peninsula Power Company began partial production with one unit during this period. On February 5 trouble caused by the travelling grate being stuck caused shut down of the plant. While the grate was being repaired a leak in the weld of a side wall tube was discovered. Both the grate and the tube were repaired and the plant was placed back in service February 6.

On April 27 the Ishpeming Plant was shut down and remained inactive for the remainder of the year. When such a generating plant is on inactive basis a considerable hazard exists in that the steam generating equipment will deteriorate very rapidly unless extreme precautions are taken to protect it. This deterioration is caused by corrosion on the water side of the boiler, caused by dampness, and on the fire side of the boiler, caused by moisture also, but the deterioration on the fire side is apt to be accelerated by the presence of sulphur from previously burned fuel. In order to protect the boiler unit the entire fire side of the boiler was washed with water under pressure and all traces of ash, sulphur deposits, etc. were removed, and then the entire surface was treated with lime water. After this was done the unit was prepared so that warmed air could be blown through all of the tubes and water passages on the water side of the boiler, and the humidity on both the fire and water sides reduced to below 20%. It will be necessary to continue the circulation of this warmed air through the boiler for the entire inactive period. This was an exceedingly dirty and disagreeable procedure but the condition of the unit while in storage will be excellent. The fact that the power plant has been prepared and is in storage in this manner precludes its being used for standby purposes and all energy which is generated by our Company for standby purposes is now being generated in the Ishpeming Diesel Plant.

Service from the transmission system operated by the Upper Peninsula Power Company during the year was satisfactory. No major equipment failures occurred during the year and no interruptions of extreme duration were experienced. Improper functioning of various relays caused some interruption and other interruptions were experienced due to wind conditions and severe lightning and electrical disturbances. Improper operation of the relays was due mainly to the fact that these relays were installed in the latter part of the previous year and had not been thoroughly tested under operating conditions. The personnel of the Company became more familiar with their operation and corrections were made in the relay settings so that by the end of the storm period this summer all of the difficulties had been overcome and the frequency and duration of disturbance was greatly reduced.

On March 6 the Mining Department made a reduction in working schedules for all of its employees along with accompanying pay cuts. Due to the operating procedure of the power department it was impossible to put this schedule into effect throughout the department at that time. However, the wage reduction was given to salaried employees and they were placed on a work schedule of three weeks out of every four weeks. At the time that the Ishpeming Steam Plant was shut down it was possible to reduce the working force and at the same time institute a schedule on hourly-wage employees so that they worked only four days a week and only three out of four weeks each month. Due to operating difficulties this plan was not extended to three employees operating isolated hydroelectric plants. The reduced work schedule and salary cut for salaried employees was abandoned September 1st and the hourly wage employees returned to four days a week every week early in October. The result of this work schedule change was such that at the beginning of the year the hourly personnel were working 50% more man days per week than were being worked at the end of the year.

ELECTRIC POWER DEPARTMENT
ANNUAL REPORT
YEAR 1958

STATISTICAL DATA - 1958

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Precipitation -	1.33	.76	.94	.94	2.16	4.72	7.56	3.70	2.13	2.57	2.79	1.21

Total precipitation at Ishpeming during 1958 - 30.81" (2.5675 ft.)
Average " " " - 30.71" (46 year record)

CARP RIVER PLANT:

Drainage area above intake dam	66.66 sq. miles
Cubic feet precipitation in 1958	4,771,375,615
Kilowatt hours generated in 1958	17,631,000
Cubic feet water utilized in 1958 (90 cu. ft. - 1 kwh)	1,586,790,000
" " " wasted over intake dam in 1958	20,772,000
" " " in Carp storage Dec. 20, 1957	372,625,940
" " " " " " Dec. 19, 1958	332,412,300
" " " decrease in Carp storage in 1958	40,213,640
Total run-off in 1958 (cubic feet)	1,567,348,360
Run-off per square mile of drainage area (cubic feet)	23,512,577
Second-feet run-off	0.748

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925
Total Precip.	30.11	26.53	38.40	36.83	25.46	31.05	29.50	27.40	30.38	33.67	21.90	22.95	20.71
Sec.-ft. Run-off	1.03	0.67	0.93	1.29	0.70	0.79	0.83	0.73	0.68	1.06	0.59	0.50	0.25

	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938
Total Precip.	35.69	29.86	36.06	32.28	23.14	36.70	31.20	32.72	32.87	27.10	30.23	30.10	35.32
Sec.-ft. Run-off	0.85	0.98	1.11	0.67	1.10	0.83	1.13	1.14	1.00	0.79	0.89	0.86	1.33

	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
Total Precip.	33.58	30.34	32.20	34.26	32.04	32.77	30.81	26.12	32.88	22.87	37.23	30.64	43.50
Sec.-ft. Run-off	1.47	1.05	0.83	0.84	1.17	0.70	0.81	0.56	0.88	0.44	0.77	1.09	1.54

	1952	1953	1954	1955	1956	1957	1958
Total Precip.	24.35	35.42	33.77	30.82	25.52	24.53	30.81
Sec.-ft. Run-off	0.69	0.85	0.84	0.93	0.77	0.687	0.748

McCLURE PLANT:

Drainage area above intake dam	140.52 sq. miles
Cubic feet precipitation in 1958 (Hoist Plant - 28.95"-2.413')	9,452,861,789
Kilowatt hours generated in 1958	42,178,000
Cubic feet water utilized in 1958 (125 cu. ft. - 1 kwh)	5,272,250,000
" " " wasted over intake dam 1958	0
" " " in Hoist storage basin Dec. 20, 1957	1,320,423,525
" " " " " " " Dec. 19, 1958	995,046,900
" " " decrease in 1958	325,476,625
" " " in Silver Lake Dec. 20, 1957	0
" " " " " " Dec. 19, 1958	0
" " " increase in 1958	0
Total run-off in 1958 (cubic feet)	4,946,773,375
Run-off per square mile of drainage area (cubic feet)	35,203,340
Second-feet run-off	1.119

	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933
Total Precip.	35.10	42.03	26.60	30.49	24.06	43.95	35.51	43.80	38.75	30.81	37.02	32.54	35.07
Sec.-ft. Run-off	1.02	1.54	0.85	0.92	0.52	1.52	1.80	2.22	1.36	1.45	1.10	1.23	1.30

	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946
Total Precip.	35.02	29.96	32.16	38.18	40.93	41.22	36.59	38.15	40.20	35.64	37.62	37.94	31.91
Sec.-ft. Run-off	1.16	0.90	1.05	1.19	1.75	1.69	1.47	1.28	1.15	1.43	1.17	1.36	0.86

	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
Total Precip.	37.27	28.81	43.28	40.65	50.90	29.27	41.56	38.13	35.70	31.71	28.78	28.95
Sec.-ft. Run-off	1.22	0.78	1.24	1.37	2.09	0.97	1.33	1.29	1.03	1.18	1.237	1.119

Average precipitation at Hoist Plant - 35.95" (38 year record)

ELECTRIC POWER DEPARTMENT

STATISTICAL DATA - 1958

Energy Delivered to Transmission System
by CCI Co. Generating Facilities

	Kwh Delivered to Lines				
	CCICo. Steam	CCICo. Hydro	CCICo. Diesel	UPGCo. Steam	Total
Jan.	2,562,060	6,930,149	69,950	2,675,120	12,237,279
Feb.	2,800,847	7,191,575	264,640	3,540,206	13,797,268
Mar.	1,804,138	5,216,090	9,120	5,040,708	12,070,056
Apr.	824,040	6,844,375	61,170	1,083,366	8,812,951
May		6,560,865	286,510	1,151,722	7,999,097
June		6,636,140	9,485	1,510,021	8,155,646
July		7,669,725		642,888	8,312,613
Aug.		6,131,005	88,585	402,116	6,621,706
Sept.		6,812,035		2,065,874	8,877,909
Oct.		7,573,015		1,101,261	8,674,276
Nov.		9,597,875	38,910	110,832	9,747,617
Dec.		8,379,610	278,305	996,516	9,654,431
Total annual use by UPPCo. of CCICo. energy from UPGCo.	_____	_____	_____	18,348,070	18,348,070
Total energy produced by CCICo. generating facilities	7,991,085	85,542,459	1,106,675	38,668,700	133,308,919

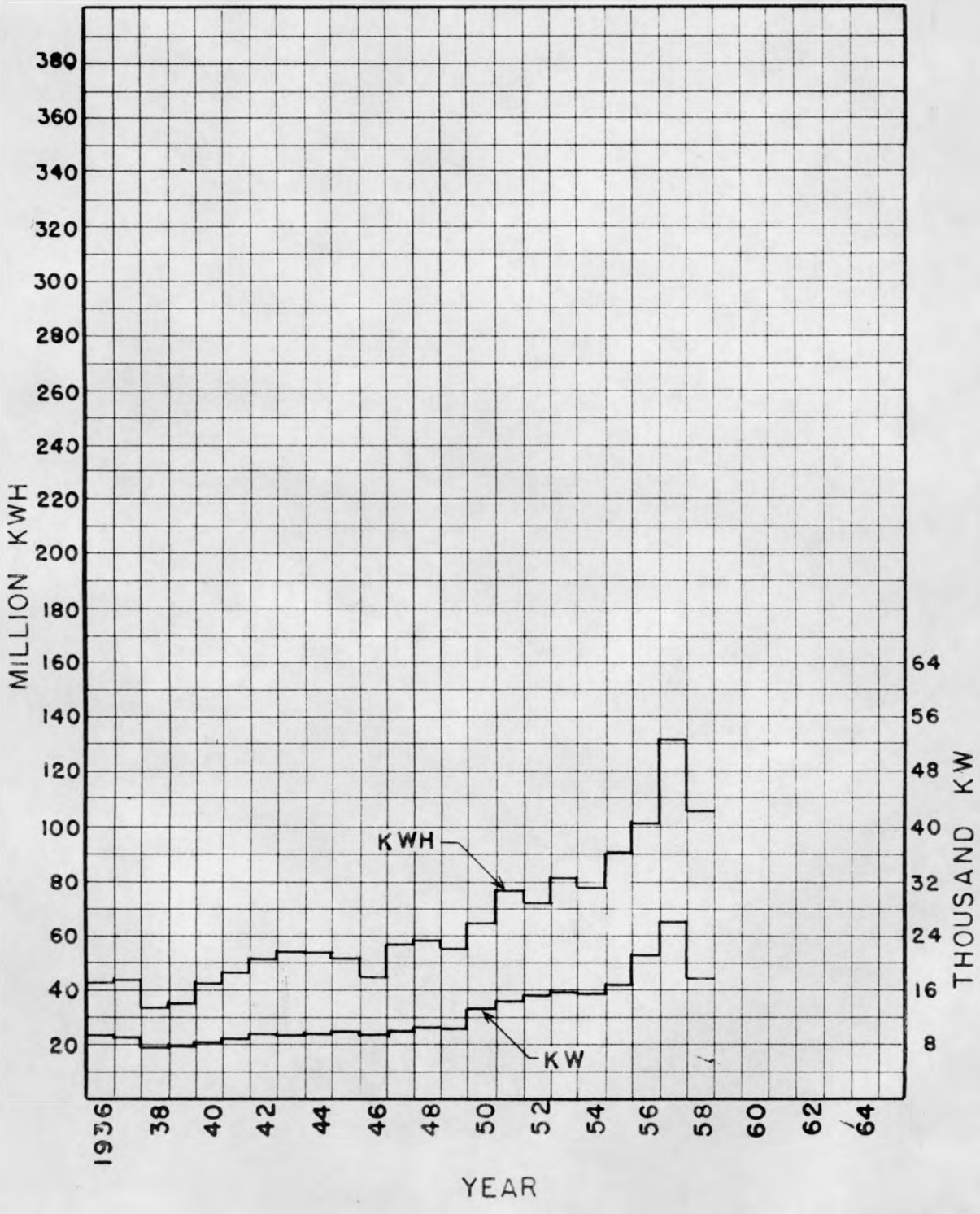
ELECTRIC POWER DEPARTMENT

STATISTICAL DATA - 1958

Utilization of Energy Delivered to
Transmission System by CCICo. Generating Facilities

	Ishpeming Steam		Hydro		Diesel		UPGCo.		Total Kwh	% of Total
	Kwh	%	Kwh	%	Kwh	%	Kwh	%		
The Cleveland-Cliffs Iron Co.			25,218,630	18.9					25,218,630	18.9
Athens Iron Mining Co.			1,352,981	1.0					1,352,981	1.0
Negaunee Mine Co.			22,686,291	17.0			7,817,418	5.9	30,503,709	22.9
Marquette Iron Mining Co.			33,903,354	25.5			11,682,679	8.8	45,586,033	34.3
Humboldt Mining Co.			2,381,203	1.8			820,533	0.6	3,201,736	2.4
Upper Peninsula Power Co.	7,991,085	6.0			1,106,675	0.8	18,348,070	13.7	27,445,830	20.5
Total	7,991,085	6.0	85,542,459	64.2	1,106,675	0.8	38,668,700	29.0	133,308,919	100.

ENERGY & POWER REQUIREMENTS
C.C.I. CO. OPERATIONS



SUBJECT: Operating Research Department - Year 1958

Mr. Hugh J. Leach
Manager, Michigan Mines

Dear Sir:

I herewith submit to you the 1958 Annual Report of the Operating Research Department. Although the department was disbanded in July, 1958, the final portion of this report, headed "Special Projects", includes the activities of the writer for the balance of the year.

Itemized below are the projects that were completed in 1958.

INCENTIVES

1. Mather Mine "A" Shaft - Revision of the inclined drift incentive.

2. Mather Mine "B" Shaft - Establish an incentive for the Raise Cage.

3. Mather Mine "B" Shaft - Drift repair work incentive study.

4. Mather Mine "B" Shaft - Long hole drilling incentive in a mining drift with a chain conveyor installation.

5. Bunker Hill - Establish an incentive and proper working procedure for driving mining drifts that use two different weights and sizes of yieldable steel arches.

6. Cliffs Shaft - Review of stoping rates.

TIME STUDIES

1. Mather Mine "B" Shaft - A study to establish the best shop layout and practices in the steel set shop.

2. Cliffs Shaft - Comparison of carburized steel drill rods with carbon steel drill rods.

3. Cliffs Shaft - Testing various manufacturers tungsten carbide bits.

4. Cliffs Shaft - Comparison of performances of drilling machines underground.

5. Cliffs Shaft - Comparison of grinding wheels for sharpening tungsten carbide bits.

6. Tilden Pit - A study of the performance of the Ingersoll Rand "Down the Hole Drill" using a 6½" Carset X bit.

GENERAL PROJECTS

1. Chain Conveyors.
2. Auger Miner.
3. Ditch Cleaners
4. Prestressed Concrete Sets.
5. Rock Drill Oils.
6. Conversion of the CP 555 to Remote Controls.
7. Miscellaneous.

SPECIAL PROJECTS

1. Bunker Hill-Maas - Study for W. A. Sterling with G. J. Holt.
2. Marquette Range Personnel - Study for W. A. Sterling with G. J. Holt.
3. Cambria-Jackson - Study for J. S. Westwater with R. L. Tobie.
4. Mather Mine - Study for J. S. Westwater.
5. Cascade - Study on reserves, analyses, ore structures, plant lay-outs, and mining plans.
6. Industrial Television.
7. Mather Mine Screening Study.
8. Pellet Plant - Car thawing equipment.
9. Raise Hoist.
10. Mather Mine "B" Shaft - Inclined drift study.

INCENTIVES

Prior to July, 1958, the Operating Research Department was requested to conduct time studies and work methods studies to establish, revise, and review incentives at all of the larger underground properties.

At the Mather Mine "A" Shaft, this department was requested to establish a revised incentive in the inclined drift because a men and materials handling car had been installed in the drift. This incentive was set up on increments to adjust for scraping distances from the drift heading to the conveyor belt.

Three incentive studies were made at the Mather Mine "B" Shaft. The first study was to establish a rate per foot of raise for the Raise Cage Method of advancing raises. The regular rate for raising by conventional methods was

INCENTIVES -contd.

$11.50 per foot of raise. The new rate that was developed for the Raise Cage Method was $8.75 per foot. The overall saving by this new method is not completely reflected by this $2.75 difference in rates. The conventional method requires two raises as compared to one for the Raise Cage Method. This would result in an actual saving of $14.25 per foot of raise advanced.

A work sample study was conducted on drift repair work at the Mather Mine "B" Shaft. After posting the data accumulated in February it was found that there was so little correlation of the information that no practical incentive could be calculated. A great deal more information would have to be obtained before a workable incentive could be developed. A subsequent reduction in manpower to further the study made it necessary to abandon this project.

The third study was a review of the long hole drilling incentive. It was revealed that due to the installation of the chain conveyor in a mining drift more drilling time was made available for the miners and a reduction of $.05 per foot from $.35 to $.30 per foot could be justified. However, the Mather Mine personnel acquiesced to the Union's statement that there was no increase in the rate of drilling, but solely in time per cycle for drilling. This new rate was discontinued.

At the Bunker Hill Mine, a new method of support in mining drifts required a time study to establish an incentive for driving these drifts. This new drift required larger cross sectional excavations at the mill locations and careful installation of these mill sets. Because of varying ground conditions, it was necessary to establish two rates, one for regular drifting and the other for drifting with pipe spiling.

Due to the high swings that were occurring in the stope miners pay at the Cliffs Shaft Mine, Mr. Marjama asked our department to assist in a review of stoping rates. It was found that back in 1948 or 1949 an additional incentive had been offered Cliffs Shaft miners by increasing their stoping rate, after 40 cars/shift, from a 82-18 curve to a 75-25 curve. Actually, this 75-25 calculation is a flatter curve or lower increment per car payment than the other mines are using. However, the increase in payment caused the Cliffs Shaft personnel concern. It was suggested that no revision in the incentive be made, but a closer control of tramming be exercised so that the contracts would not go above the 40 car per shift average.

This situation is peculiar to the Cliffs Shaft alone because of their system of accumulating a pile of ore to use as a means of mining the backs of stopes. This results in no production from a contract in some months and an excessive amount when the accumulated ore is being moved. As previously mentioned, closer control is being exercised in these cases.

TIME STUDIES

The Mather Mine "B" Shaft personnel requested a work methods study of the steel set shop to establish the best shop layout and shop practices that could be instituted in the space available. When the study was completed, a new layout of equipment was made, and the work procedure of the men involved was altered. These changes, with the addition of some equipment, provided a much more efficient operation. It resulted in the immediate reduction of one man and an ultimate reduction of two men from this five man operation.

TIME STUDIES -contd.

With the assistance of Mr. J. P. Meyers, Engineer at the Cliffs Shaft Mine, numerous equipment testing studies were conducted at the Cliffs Shaft Mine.

A test of carburized steel proved that it wasn't economical to use this steel because of the higher initial cost, as well as lower drilling footage, than the carbon steel presently in use.

Several comparison bit tests were made with favorable results. Continued testing is being done in mining contracts to determine whether the same favorable results will be obtained in actual mining operations. These tests will continue into 1959.

Other tests conducted at the Cliffs Shaft Mine were on drill machines and grinding wheels for carbide insert bits.

The experimental model X-793 Ingersoll-Rand integral leg was compared with the other production machines underground at the Cliffs Shaft Mine. The X-793 Model proved to be 18.5% to 64.5% better than other machines in its weight class in the penetration tests. The handling ability and general performance of this machine were satisfactory. Because the machine is so new, no maintenance costs were available.

In the grinding wheel tests, the Bay State "L" hardness wheels outperformed the comparable Carborundum wheels by 28%. Mr. Meyers estimated that by using Bay State wheels an approximate saving of $525.00 per year could be realized at the Cliffs Shaft Mine.

A study was undertaken at the Tilden Mine to determine the efficiency of the Ingersoll-Rand "Down the Hole Drill" when drilling in the West Pit. This machine was drilling with the 6½" Carset X bit. The overall performance of the drill was satisfactory, however, a trial of a larger machine with a 9" bit has been requested.

GENERAL PROJECTS

1. Chain Conveyors

The 1957 Annual Report for the Operating Research Department discussed in general the savings that could be realized by the use of chain conveyors rather than scraper hoists underground. In an additional effort to investigate the degree of savings in labor and wages, the Mather Mine "B" Shaft agreed to keep special records on scraper hoist maintenance costs for 1958. However, due to the curtailment of operations and the cut-back in office and supervisory personnel, these records were not obtained. From this information, a final report on the justification of the use of chain conveyors in suitable applications was to have been written.

When the chain conveyors were originally introduced underground, it was estimated that if it was possible to get 70,000 tons of ore over a conveyor before the chain was replaced it would be considered an economical operation. During 1958, several chain conveyors have handled over 120,000 tons before the chain was replaced, and one conveyor has handled 171,785 tons of ore and will continue in use when this area is back into production. We have estimated that the chain is providing us with over 50% more life on the average than had been originally estimated.

1. Chain Conveyors - contd.

In January, 1958, a chain testing machine was devised and a record of chain strengths after a given period of use was started. When the W. B. Thompson Company and Walter Herold heard about our efforts, they volunteered the services of the Thompson Company personnel and Walter Herold's shops facilities to handle this testing program if they, in turn, could utilize the information. Presently, several chain conveyors at each property are delegated as the test units. A sample of chain and an over-all inspection, with photographs, is being made of these conveyors for every 10,000 tons of ore conveyed. In another year's time, a good set of performance standards can be formulated for the operation and life expectancy of all parts of the chain conveyors.

During the latter part of 1957, this department started designing a new Z section pan for the chain conveyor. We estimated that a $100.00 or 35% saving could be realized per pan if the mine shops would build these pan sections. The drawings were completed in June, however, due to the reduction in labor force at the mines nothing has been done since July.

Another equipment supplier heard of our Z section pans and in December supplied the Mather Mine "A" Shaft with a chain conveyor using this type of pans.

From the time that the chain conveyors were introduced until the time that our department was disbanded, whenever a new application for a chain conveyor was to be made or whenever out of the ordinary trouble was encountered in the operation of a conveyor, members of this organization were used as designers, supervisors, and trouble shooters.

2. Auger Miner

After drilling with the auger miner had been completed at the Bunker Hill Mine late in 1957, it was decided to transfer this equipment to the Mather Mine "A" Shaft to mine the interbedded ore. The 7200 X-Cut on 7th Level was picked for the initial trial because due to the flattening of the dip of the orebody approximately 160' of interbedded ore was exposed in this drift.

The plans called for drilling an upper and lower hole on each side of the drift. In order to drill the upper hole, it was necessary to extend the hydraulic jack legs four feet above the rails. This set-up wasn't very safe so several devices had to be designed to insure the stability of the rig while drilling. Several other revisions were made to improve the operation of the auger.

Since the drilling was to be done from the level elevation, a chain conveyor installation had to be designed so that the ore that was mined with the auger could be elevated into tram cars. This design included double vertical and horizontal curves which were a source of trouble at the outset until the proper tensioning of the side chains was accomplished.

During the time that the conveyor was installed and the auger equipment was being assembled, it was necessary for men from our department to supervise the job. In May, when augering was begun, a member of this department was assigned to this project on a steady basis because operators had to be trained, and due to the hard ground encountered, several new designs of the auger head had to be made to cope with the ground conditions. This man stayed on the augering job until the department was disbanded in July.

3. Ditch Cleaners

There are two types of ditch cleaners in use in the underground mines, the Gafner Hydraloader and the Sherman backhoe.

The Gafner Hydraloader is a pulpwood loader that was redesigned by our department for ditch cleaning. The unit is mounted on a regular mine truck and is cageable. All motions of the loader are hydraulically controlled and the hydraulic pump is operated by a 5 h.p. D.C. electric motor that can be powered from the trolley line or a battery locomotive. This loader can load directly from the ditch into cars.

The Sherman backhoe type ditch cleaner is also completely hydraulically controlled. A 10 h.p. D.C. motor is used to run the hydraulic pump. This unit does an excellent job of digging very hard compacted material. It does a fairly good job of cleaning mud, however, it cannot load directly from the ditch into tram cars because of head room clearance. This unit is not cageable.

A comparison of performance of these two loaders was made at the Mather Mine "A" Shaft and it was decided that both of these ditch cleaners have a definite application in our underground properties.

4. Prestressed Concrete Sets

The use of prestressed concrete sets was tried at the Mather Mine "B" Shaft. These sets were manufactured by the Northern State Dunbrik Company of Negaunee. The sets were very heavy and cumbersome to handle, both in transporting and in the mining contracts. In their use for support in a transfer drift, in an area that wasn't considered to be too heavy ground, the sets did not prove successful. It was observed that the caps would fail at both ends at the joggles. The legs would shear at the top ends at an angle of 45° across the leg. It was assumed that because of the rake of the leg the concrete was not able to provide its strongest element which is compression. The caps, in turn, were built heavy in the middle with a much smaller section at the joggles where an equivalent amount of support is required and thus failed at those points. No further work has been done with the concrete sets.

5. Rock Drill Oils

At the request of Mr. Iver Johnson, Purchasing Agent, an investigation of rock drill oils was started. Mr. Johnson pointed out that there is a big variation in the prices of rock drill oils as supplied by the various oil companies. To be specific; the Standard Oil Company was supplying our company with their Non-Pareil Rock Drill Oil at $0.82 per gallon (federal tax included) while the Texas Company was willing to supply us a comparable oil for $0.52 per gallon (federal tax included).

A comparison of specifications of the different companies' products didn't prove anything conclusively. Letters were then written to the American Society for Testing Materials, The M. A. Hanna Company, The Anaconda Company, and the Climax Molybdenum Company to get the benefit of any information or practical experience that they might have that could be made available to us.

The American Society for Testing Materials didn't answer at all. Climax Molybdenum Company did not have any information because they had never delved into the investigation of lubricants. The M. A. Hanna Company of Iron River were using both the Standard Oil and Texaco products, but preferred the Texaco rock drill oil strictly from a cost standpoint because they had never made any performance comparisons. The Anaconda Company had made very extensive tests and Lester Bishop of

5. Rock Drill Oils - contd.

the Anaconda Research Department provided us with their results. The Texaco EP rock drill oils were ranked highest by them on a performance basis.

This information was submitted to Mr. Johnson and the operating superintendents and presently the mines are using the Texaco product.

Considering the fact that our company used over 13,000 gallons of rock drill oil in 1958, a $0.30 per gallon saving amounts to approximately $4,000.00 per year.

6. Conversion of the CP 555 to Remote Controls

The Mather Mine "B" Shaft operators requested our department to investigate the merits of a remote control conversion unit that had been developed by their drill repairman, Mr. Peter Belpedio, for the CP 555 long hole rotary drill machine. Our study approached the subject from a production, safety, and cost standpoint.

Production was not improved appreciably, however, from a safety angle the cost of conversion could readily be justified. The cost of the conversion amounted to $99.35.

The remote controls will eliminate the numerous slight and compensable hand injuries that have occurred during the operation of the rotary drill. With remote controls, it also permits the use of the rotary drill near mill openings without endangering the miner as it had in the past. It also places the miner further away from the rotating rods, which in June, 1954 almost cost the life of a miner when his clothes became entangled with the rotating rods.

7. Miscellaneous

Early in January, 1958, the Pellet Plant was having considerable trouble with their hot materials product belt, and they were afraid that they might be forced to shut down. Mr. Rembold asked our department if we thought a chain conveyor could be substituted for this belt conveyor until a replacement belt could be delivered. We knew that the chain conveyor could handle the pellets up the incline, but we couldn't predict whether the pans would warp due to the heat. Nevertheless, arrangements were made with the underground mines for a chain conveyor and the Operating Research Department was prepared to install the conveyor whenever it was needed. If the chain conveyor would have had to be used, it would have required removing all the belt idlers and the chain would have been installed on the conveyor belt deck. Fortunately for the Pellet Plant, it was not necessary to use the chain conveyor, thus eliminating a great deal of extra work.

Members of this department were called upon to observe mining or other operations to determine whether improvements could be made. These projects would normally result in a methods improvements time study that would revise the working procedure to improve the output of the persons involved.

In February, the Bunker Hill-Maas Mine requested that we conduct a mine water survey to try to reduce the moisture in the product. After two weeks of survey with the Mine Superintendent, a 2% reduction in moisture in the mine product was realized.

SPECIAL PROJECTS

Due to the economic conditions affecting the iron ore industry, Mr. W. A. Sterling, President and Chairman, requested Mr. Grover J. Holt, Assistant to the President, and the writer to make several special studies of the operations on the Marquette Range, that would result in curtailment of production and layoffs of employees. These studies were to be made entirely independent of the operators, and were to establish the most suitable operating schedules and working force to insure The Cleveland-Cliffs Iron Company a profitable year despite the economic dilemma confronting independent iron ore producers.

1. Bunker Hill-Maas

At Mr. Sterling's request, a study was made of the Bunker Hill-Maas Mines. The report was to contain recommendations for the best method of obtaining a small operation and still keep the mines alive; yearly maintenance cost figures if these mines were shut down; and the cost if the mines were shut down and flooded without maintenance.

On the basis of the findings of this report and the independent study prepared by the operators, the Bunker Hill-Maas Mines continued to operate in 1958.

2. Marquette Range Personnel

In June, Mr. Sterling requested that Mr. Holt and the writer make a survey of all the salaried and hourly rate employees on the Marquette Range and determine the maximum economic reduction that could be made in the overall working force, on the curtailed production schedule, without hurting the Company's operations. This study was also conducted independently of the operators. When the two studies were completed and compared, a final recommendation was made to Mr. Sterling and a layoff was made relative to the findings of the two studies.

Excluded from these studies were the clerical personnel which was handled by Mr. W. E. Dohnal.

3. Cambria-Jackson

In February, Mr. J. S. Westwater requested the writer to investigate the operations of the Cambria-Jackson Mine to prepare a Budget Cost of Production for 1958, and to recommend to Mr. R. L. Tobie, Superintendent, any possible means of reducing costs. It was recommended that the watchmen at the Mather Mine "B" Shaft could include the Cambria plant as part of their duties, thus eliminating three men from the payroll. A reduction in the maintenance crew was discussed with Mr. Tobie which also resulted in a reduction in the labor force.

4. Mather Mine

In August, Mr. Westwater requested that the writer make a study of the most economical operating schedule for the Mather Mine on a 1,500,000 total production basis. Production schedules, working schedules, estimates of the labor force, and the resulting production costs were prepared for both shafts.

4. Mather Mine - contd.

A two shifts per day, four days per week, no "honey-do" week schedule proved to be the most economical. This new operating schedule resulted in another reduction in the labor force.

5. Cascade

On December 17, 1957, Mr. Boyum submitted a report entitled "Data for Special Reserve Study" that indicated the total tonnage of estimated Cascade direct shipping ore. This information had been accumulated as the drill holes had encountered the ore with no reevaluation of the entire drilling data. It was requested of the Geological Department to have an independent estimate made by one of the other departmental geologists. It was suggested that he check all the core, all of the analyses, and calculate a new estimate. The estimates checked within 3% of each other, which was assurance that the original estimate was relatively correct.

At the same time it was suggested that a complete chemical analysis was to be made of the Cascade core for the possible presence of the following elements: arsenic, nickel, sodium, zinc, potassium, copper and chromium. Our Chemical Laboratory found the samples to be free of these elements. As a further check, samples were sent to Michigan Tech and a spectrographic analysis also proved the samples were free of these other elements.

Another study was made to compare the Diamond Drill core analyses with actual mining analyses. Experience at the Mather Mine "B" Shaft indicated that actual mining analyses were always somewhat lower than the drill core analyses. A check was made at the Mather Mine "B" Shaft and an average of both the 7th and 8th Levels showed that mining samples were 2.25% to 2.50% lower in iron than the drill core samples.

Mr. Westwater then requested the writer to try to establish a moisture content of the Cascade ore. It was decided to take core samples of the Mather Mine, Bunker Hill and Maas ores and compare them with the Cascade core to see if any basis for establishment of a moisture content could be made. Upon visual inspection, it was decided that the Cascade ore compared the closest with the Mather Mine ores.

In trying to justify the observations made it was decided to ask Mr. Tsu Ming Han, Mineralogist, to run a microscopic analysis of the ores. Mr. Han was informed of what we were trying to accomplish. He stated that he could not only make a grain size comparison, but he could establish the porosity, the rate of absorption and evaporation of water, and the percentage of the different minerals present in the various ores. Mr. Han believed that he could, through his methods of study, give us a much more accurate picture of what to expect in moisture content and structure at the Cascade.

On the basis of the tests conducted by Mr. Han and Mr. Don Lukkari, Geologist, it was concluded that the Cascade ore is essentially made up of more than 60% non-porous martite and less than 40% soft earthy hematite. Physically, the Cascade ore is a fairly hard porous and granular ore having a maximum moisture content of not more than 9%.

In light of all the information from actual mining experience, recheck on drill analyses, and Mr. Han's and Mr. Lukkari's report, it is safe to assume that for the 40,362,000 tons of standard ore at the Cascade, the estimated average analysis will be between 54.50 and 55.00% natural iron.

5. Cascade - contd.

The report by Messrs. Han and Lukkari uncovered an entirely new approach to the evaluation of iron ores, and may be invaluable to the Company in future studies.

Early in 1958, we were informed by the Geological Department that the Richmond Pit contained a considerable amount of M.O.C. ore that could enter the mining picture. This possibility made it necessary to investigate an alternate site for the surface plant of the underground mine. Seismic surveys were run to determine the best possible location for the alternate site, however, due to the reduction in personnel, the job was never completed.

Several letters were written relative to the mining methods and the most ideal location along the footwall to begin mining. Due to the estimated flat dip (-20°) of the upper part of the orebody, the idea of initiating the mining in the lower portion of the orebody has been considered. There are several reasons in favor of this approach, mainly: the mass of the orebody is located in the middle of the lower two-thirds of the present known orebody, the center of the mass of the orebody is the shortest distance to the original shaft location and by not mining the top one-third of the orebody a cave through to surface would not occur as rapidly, thus minimizing surface water problems. Because of the flat dip of the footwall, mining in this method should not hinder any future mining of the upper portion of the orebody.

Many problems remain untouched, but nothing can be definitely resolved until a permanent shaft location is established and the opportunity for further study is granted.

Because of the need from a safety, a production, and a ventilation standpoint, two shafts 75 ft. apart have been planned for the Cascade. It occurred to us that presently Michigan does not have a mining code, but with the Union's persistent efforts to get a mining code, the possibility of a minimum distance requirement between shafts may materialize. An investigation of minimum distance requirements between shafts of the various states, and Canada, that do have codes were made. It was found that the distances varied from 30 ft. to 200 ft. with several states not mentioning a minimum spacing. The study showed that the average or most common spacing was 50 ft. Mr. Clancey, Attorney, was consulted and he stated that if we did have our 75 ft. distance between shafts prior to any mining code that might be passed in Michigan, the State would not require an operating mine without the minimum distance between two outlets to sink a third shaft in order to come within the terms of the legislation. It was also Mr. Clancey's opinion that with most of the states having a 50 ft. spacing between outlets, Michigan would very likely hold to the same spacing.

The Mechanical Department has made a drawing of our proposed two shaft, headframe, and engine house layout.

A model of the Cascade orebody was constructed by Mr. Edward C. Rosar of the Operating Research Department with the help of Mather Mine "B" Shaft carpenter shop personnel. This model is presently situated in the Engineering Building.

No further work was done on the Cascade East End Project.

6. Industrial Television

At the request of Mr. Fayette Brown, Jr., Assistant Vice President, a report was prepared on the "Use of Industrial Television on the Marquette Range". The report contained information on past, present, and future applications of television in the plants and underground mines. It showed the savings in labor and wages that are being realized by present installations and where future applications can justify similar economies.

7. Mather Mine Screening Study

In September, plans were made to run a series of screening tests of the Mather Mine ores at the Ore Improvement Plant to establish the maximum moisture content of the ores that can be screened without drying. This test was necessitated by the present demand for the 3/8" sinter feed product. The tests were to determine whether screening at the mines would be feasible, or if drying of the mine product would be required to efficiently produce sinter feed material.

The results of the test proved that it was difficult to establish a maximum moisture content of Mather Mine ores that can be screened without drying, because of variations in structure and mineral content of the ore. It was agreed that the best and surest means of determining a screenable product is by visual inspection.

It was concluded that in view of the fact that the Bethlehem Steel Company is requesting a sinter feed product with a lower moisture content than the 7.68% that was delivered in 1958, drying before screening will be necessary to produce the desired product.

In conjunction with the screen tests, two new pieces of equipment were also investigated. A Bixby-Zimmer loop deck screen cloth was installed on one of the screens. Screening efficiency, from the point of view of a sharp break in oversized and undersized product, was not improved, however, this screen deck did not blind over because of build up at all. In this respect, the screen did operate more efficiently than the Ludlow-Sayler cloth that is normally used at the Ore Improvement Plant.

Additional screening studies will be conducted in 1959.

The other equipment investigated at this time was the installation of Chromalox infra-red heaters. The claim was that these heaters would reduce the moisture content of the ore as it passed over the screen, which would result in improved screening efficiency and also improve the product by increasing the natural iron through this moisture reduction. The tests proved that there was no detectable reduction in moisture, however, the Chromalox heaters did keep the top deck of the screen completely void of build up, while the screen that didn't have the heaters required constant attention to eliminate this build up of material. It was agreed that the heaters did an excellent job in this respect.

8. Pellet Plant

The supplier of the Chromalox infra-red heaters requested permission to quote on an ore car thawing unit for the Pellet Plant which would purportedly do a better job of thawing cars than the proposed new thaw shed. The initial cost of the unit was comparable to the thaw shed, however, the operating cost was prohibitive. The Chromalox infra-red heaters would consume $14,400.00 worth of electricity in a normal operating year compared to $2,000.00 worth of fuel oil for the conventional thaw shed.

9. Raise Hoist Method of Advancing Raises

In December, Mr. H. J. Leach, Manager, circulated some information on a new type of a "Raise Hoist" or "Raise Platform" which is being developed in Sweden for advancing raises. Mr. I. G. Johnson was requested to contact the Alemac Works of Sweden to get additional information. The Raise Hoist is a self propelled platform that rides on a gear-toothed rack that is rock bolted in sections to the hanging of the raise. The method of raising is similar to the working cycle employed by the Raise Cage.

This equipment is being investigated because either the Raise-Hoist or the Raise Cage will be used to drive the pilot raise for the Mather Mine "A" Shaft men and materials handling winze inside on 10th Level.

This project will be completed in 1959 .

10. Mather Mine "B" Shaft Inclined Drift

A study is being initiated to determine the best mucking and materials handling equipment for advancing the 10th to 12th Level Mather Mine "B" Shaft inclined drift. Work methods studies are being calculated to compare loading machines with scraper hoist operations. Studies are also being made of single skip, two skips with a California switch, and shuttle belt materials handling setups.

This is a 1959 project.

CONCLUSION

Prior to the termination of the Operating Research Department's activities in July, 1958, various other projects were in the process of study and resolution. The most important of these were: a complete report on chain conveyors - their application and the savings that can be derived; and a compilation of information on the cost of operating loaders underground. Another important project that was left incomplete, as far as the Operating Research Department was concerned, was the Auger Miner.

The members of the department felt that an important function was being performed by this organization. Our belief, and the opinions volunteered by the operators, is that such a department has a definite place in a progressive company such as The Cleveland-Cliffs Iron Company, particularly, when wages continue to climb.

John M. Haivala

John M. Haivala
Operating Research Department

JMH/oa
1/20/59

REPORT OF GEOLOGICAL DEPARTMENT FOR YEAR ENDING DECEMBER 31, 1958

CONTENTS

Summary of Departmental Activities

SUMMARY OF DEPARTMENTAL ACTIVITIES

The following is a brief summary of the Departmental highlights in the Company's 1958 exploration activities:

1. 1958 - A Recession Year

The year 1958 was termed a recession year with greatly reduced volume of business activities. We made a strong recommendation that the Company expand its exploration activities during the recession year as numerous opportunities are available under these conditions, and many times at reduced rates. This was summarized in our General Exploration Report No. 42, dated April 7th. The opportunities are available, particularly to a company in such strong financial condition as Cliffs.

Staff reductions were made in the early part of August effective August 15th concurrently with the reductions being made at the mines and at the other departments. A total of five salaried people were dropped from the Department. This reduction, together with the reductions made last fall, amounts to a total reduction of 66% in the salaried personnel and 91% in the hourly rate personnel in the exploration group.

2. Exploration - Latin America

During the year 1958 land offers were investigated in Peru, Venezuela, and Colombia. In the case of Peru, the Exploration Department recommended an active program because of the opportunities available, being similar to the one recommended by Mr. Boyum following his trip to Peru in 1957. A program was also recommended for Colombia. In the case of Venezuela, a joint venture with the Venezuelan Government was proposed and developed.

3. Quebec Cobalt Property

During 1958 the Jones & Laughlin Steel Corporation offered Cliffs a half interest in their Quebec Cobalt property near Mount Wright. Cliffs secured an option. The property was visited by Mr. Boyum in July.

4. Missouri

A program of primary exploration was initiated in the fall of 1958 to explore a number of aeromagnetic anomalies, particularly in Washington County.

5. Wisconsin Exploration and Lease Forms

The exploration of the magnetic and gravity anomalies, particularly in Juneau County, was continued from 1957 and concluded. The source of the anomaly turned out to be massive greenstone.

A most significant contribution, however, was made in the development of the option and lease form, particularly with the evolution of the earned royalty system developed by Mr. Robert Fountain.

6. Operation Overthrust - Canada

Throughout the year 1958, Mr. R. W. Riedel continued his geological and geophysical studies of the data submitted through the Hunting Company's "Operation Overthrust". Mr. Riedel worked jointly for the Consolidated Mining & Smelting Company and Cliffs of Canada.

7. Albanel Minerals Summary Report

The Summary Report on the Albanel Minerals exploration work was completed in September, 1958. This represented a considerable amount of effort from the Ishpeming-Port Arthur and Ottawa staffs of both Cliffs and M. J. O'Brien.

8. Open Pit Mapping

The detailed geological work at Humboldt and Republic Mines continued to make a substantial contribution to the mine operations.

9. Michigan Basin Geological Association

The Department was a joint host to the Michigan Basin Geological Association meeting on the Marquette Range on June 21st and 22nd.

I. STAFF

A. Distribution

Ishpeming, Michigan continued to be the general headquarters for the supervision of all of the Company's exploration activities in all geographical areas. The district offices were maintained at Hibbing for the Minnesota Area and the Port Arthur, Ontario and Ottawa, Ontario for the Canadian activities.

Exploration activities continued to decline during the recession year. Staff reductions were made in the early part of August effective August 15th concurrently with the reductions being made at the mines and at the other departments. A total of five salaried people were dropped from the Department. This reduction, together with the reductions made last fall, amounts to a total reduction of 66% in the salaried personnel and 91% in the hourly rate personnel in the exploration group.

The general organization of the Department continued in a similar manner to previous years. There was a general deterioration in the liaison with the Canadian activities.

TABLE I

GEOLOGICAL DEPARTMENT

Burton H. Boyum, Chief Geologist

MICHIGAN

Gerald J. Anderson, Michigan District Geologist

EXPLORATION DRILLING DIVISION

Gerald J. Anderson, Supervisor
Carl Ostlund, Foreman (A)
Eino O. Kujala, Diamond Drill Clerk

DRAFTSMEN

Gideon S. Johnson (B)
Donald R. Nankervis

SECRETARIAL

Mrs. Belle Bloch
Klara Marie Hult (C)

GEOLOGISTS

Paul R. Bluekamp
Ted Engel, Jr.
Lee Erickson
Donald R. Lukkari (D)
James W. Villar (E)

TECHNICIANS

John V. Larson (F)
Robert H. Mayrand (G)

MICROSCOPY

Tsu-Ming Han (H)

(A) Change of Status, Sub-supervisor, August 15, 1958
(B) Transferred to Engineering Department August 15, 1958
(C) Transferred to IBM Department July 21, 1958
(D) Started full-time September 1, 1958
(E) Resigned September 15, 1958
(F) Laid off August 15, 1958
(G) Started August 15, 1958
(H) Transferred full time to Metallurgical Department August 1, 1958

MINNESOTA

E. Richard Randolph, Minnesota Geologist

Temporary Field Staff

Keith C. Roberts, Geologist

U. S. GENERAL

E. J. Rex, Project Supervisor (started August 15, 1958)

CANADA

Cliffs of Canada, Ltd.

Dr. M. W. Bartley, General Manager
Dr. W.L.C. Greer, Geologist
R. W. Riedel, Geologist

Temporary Field Staff

G. L. Colbourne, Geologist
J. M. Neilson, Geologist
S. F. Leaming, "
W. L. Partington, Prospector
J. R. Bussiere, "

ALBANEL MINERALS, LTD.

Dr. M. W. Bartley, Resident Manager
W. R. Sutton, Exploration Supervisor
R. W. Riedel, Geologist

Temporary Personnel

P. Bronsseau, Geologist
T. T. Quirke, Jr., "
J. M. Neilson, "
T. LaRose, Draftsman
C. Coom, "
M. Coom, "
J. Mattawashish "
P. Mattawashish "
J. Maki

B. Man-Hour Summary

The following Table II is the hourly rate personnel carried on the General Storehouse payroll as members of the Exploration Drilling Department:

TABLE II

DISPOSITION OF HOURLY RATE PERSONNEL
GENERAL STORHOUSE PAYROLL

Total Days Worked	254
Saturdays & Sundays	104
Holidays	7
Days Lost	**
Total	365

Description	Ave. No. Men	New Hire	Separations	Total Hrs. Worked	Labor Costs
Subsupervisor	½	1*	-	900	3,053.71
Runners	7.5	0	8	10,489¼	30,194.97
Helpers	4.5	1	20	6,009 3/4	14,720.24
Total	12.5	1	28	17,399	47,968.92

* - Change of Status
** - Impossible to calculate because the surface crews and the underground crews worked different schedules.

Table III shown below is a recapitulation of the various components of the Exploration Staff:

TABLE III

MAN-HOUR SUMMARY

	Men	Hours	Dollars
A. MICHIGAN			
1. Geological (Account 426)			
Permanent	10¼	18,392	$61,909.00
2. Drilling Division (Account 435) (Does not include contract labor)			
Labor	12	16,499	$47,968.92
Supervisors and Clerks	2¼	4,556	11,318.00
Sub-Total	14¼	21,055	$59,286.92
Total for Michigan	24½	39,447	$121,195.92
B. MINNESOTA (Account 326)			
Permanent	1¼	2,257	$ 9,098.00
Temporary	1	172	450.00
Foremen	7	838	—
Total	9¼	3,267	$ 9,548.00
C. U. S. GENERAL & FOREIGN (Account 436)			
Permanent	½	1,109	$ 4,948.00
D. CANADA			
1. U. S. Charges (Account 439)			
Permanent	1¼	457*	$10,706.00*
2. Cliffs of Canada, Ltd.			
Permanent	3	5,496	$16,525.00**
Temporary	5	4,640	8,905.00**
Sub-Total	8	10,136	$25,430.00

	Men	Hours	Dollars
3. Albanel Minerals, Ltd.			
Permanent	3	4,832	$ 16,875.00**
Temporary	9	2,560	4,427.00**
Sub-Total	12	7,392	$ 21,302.00
Total in Canada	17	17,582	$ 46,732.00
Total Canada (Includes U. S. charges)	17¼	18,039	—
GRAND TOTAL (ALL AREAS)	51½	61,862	$182,423.92

* - Total salary of one permanent employee in Canada plus distribution of Chief Geologist time and Permanent employee salary and time given under Cliffs of Canada, Ltd., and Albanel Minerals, Ltd.

** - Canadian Dollars

The following tabulation, Table IV shows the distribution of the professional members of the Geological Department by projects, during part or all of 1958:

TABLE IV

DISTRIBUTION OF PROFESSIONAL EXPLORATION STAFF
DURING PART OR ALL OF 1958

MICHIGAN

Operating Mines

Bunker Hill Group	Ted Engel, Jr.
Cambria-Jackson	Paul R. Bluekamp
Cliffs-Shaft	James P. Meyers
Mather Mine "A" Shaft	Lee Erickson
Mather Mine "B" Shaft	Paul R. Bluekamp
Humboldt	James W. Villar) Donald R. Lukkari)
Republic	Donald R. Lukkari) James W. Villar)
Ohio	James W. Villar
Tilden	Donald R. Lukkari

Exploration Projects

Empire Phase II	Donald R. Lukkari
Isabella	" " "
Ogden Schoolhouse	" " "

II. GEOLOGICAL AND GEOPHYSICAL FIELD WORK AND SURFACE EXPLORATION

A. Michigan

1. Empire Mine Development - Donald R. Lukkari, Geologist

No field work was performed on the Empire Mine area during the year. A minor amount of office work consisted of posting the Phase II drilling results on the geological cross-sections.

The last hole of the Phase II drilling program was completed early in the year. Hole #36 intersected the Class I material 600 feet north of the previous drilling. It showed the Class I material to be narrowing somewhat and seems to tie it in with the Class II material intersected in the southern-most Belleview holes. A total of 369 feet was drilled in Hole #36 during the year.

In addition to the Phase II drilling, two short holes were drilled as part of the Winke experimental drilling program to test the near-surface material along the same coordinate as Hole #36 (Figure 1).

2. Cascade District - Donald R. Lukkari, Geologist

a. Cascade East End Development

Field work in the Cascade East End Area consisted of a refraction seismic survey to determine ledge topography. The area covered by the survey is shown on Figure 2. The purpose of the survey was to determine the possibilities of draining the area by dredging operations provided a channel exists in the ledge. Additional information will be necessary before the survey will be complete. However, information obtained to date indicates a channeling of the ledge in a north-south trending direction.

A minor amount of office time was spent estimating ore tonnages at various elevations for preliminary mine planning.

b. Isabella Area - Donald R. Lukkari, Geologist

The drilling program in the Isabella area continued until August, 1958. Hole #5 was completed and three more holes were drilled during the year for a total footage of 1,696 feet.

The material north of the Isabella Dike was tested by the last two holes. This material proved much less uniform than south of the Dike. Several lean portions of partly oxidized carbonate iron formation were intersected which lowered the overall test results. The latest estimate shows 38,281,000 tons of Class A crude and 43,284,000 tons of Class B crude material. The drill hole locations are shown on Figure 2.

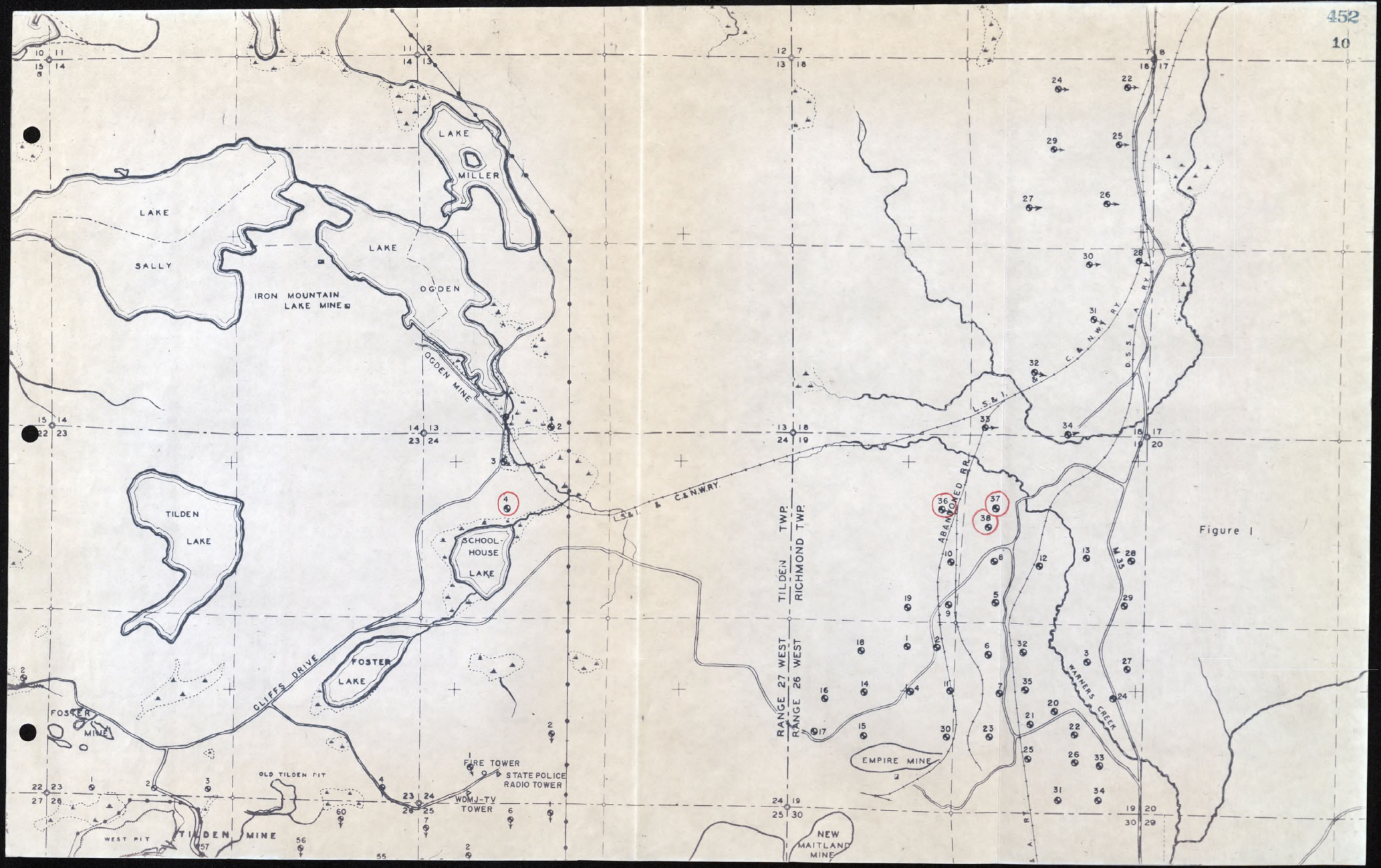

LAKE
MILLER
LAKE
SALLY
IRON MOUNTAIN
LAKE MINE
LAKE
OGDEN
OGDEN MINE
TILDEN
LAKE
SCHOOL-
HOUSE
LAKE
FOSTER
LAKE
CLIFFS DRIVE
FOSTER
MINE
OLD TILDEN PIT
WEST PIT
TILDEN MINE
FIRE TOWER
STATE POLICE
RADIO TOWER
WDMJ-TV
TOWER
L.S.& I.
C.& N.W.RY.
ABANDONED RR.
TILDEN TWP.
RICHMOND TWP.
RANGE 27 WEST
RANGE 26 WEST
EMPIRE MINE
NEW
MAITLAND
MINE
WARNERS CREEK
U.S.S.& I. RY.
C.& N.W.RY.

Figure 1

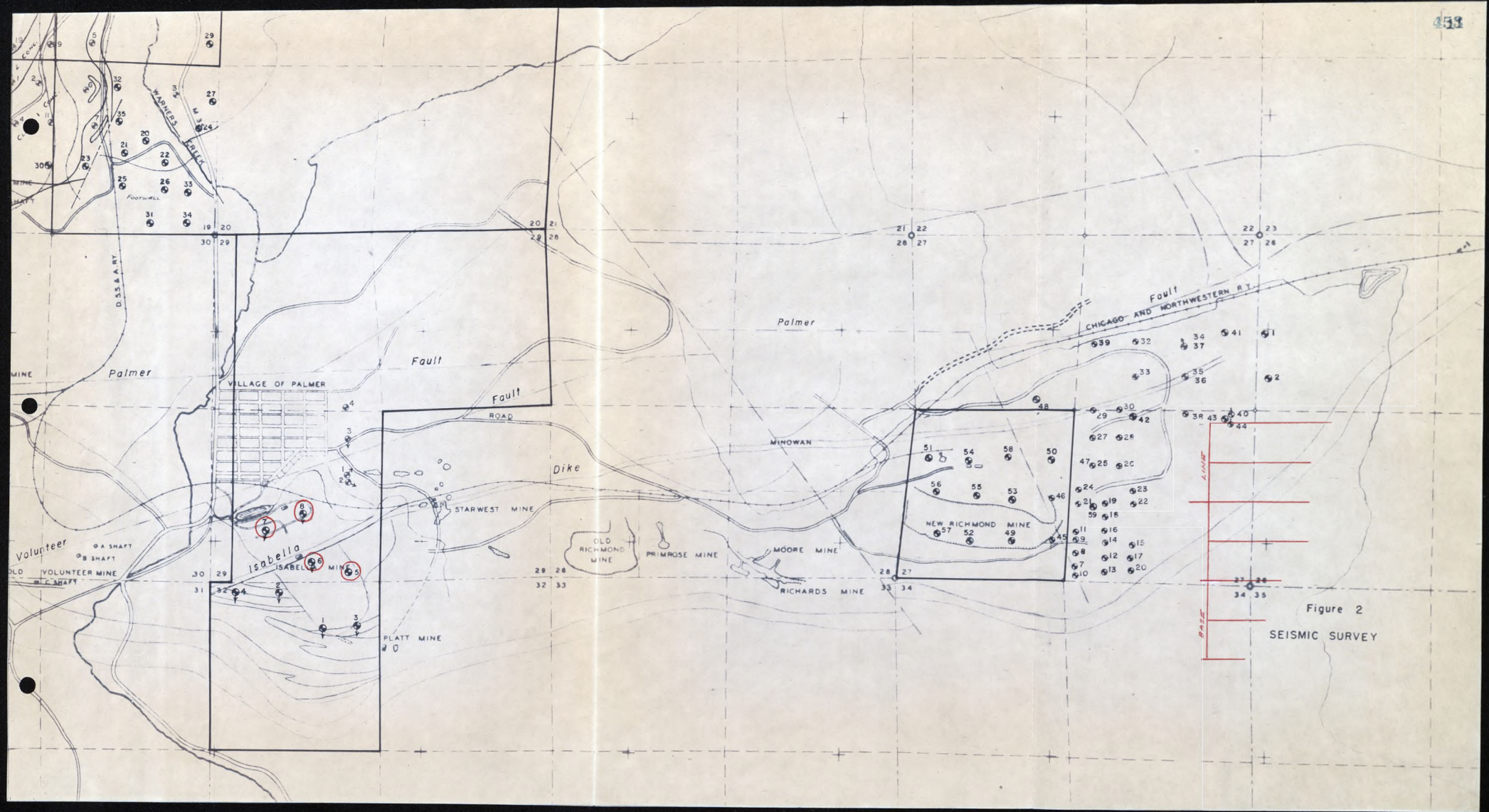


Figure 2

SEISMIC SURVEY

3. Ogden-Schoolhouse Lake Area - Donald R. Lukkari, Geologist

The drilling program in the Ogden-Schoolhouse Lake Area was concluded early in the year with the completion of Hole #4. The footage drilled was 875' in Holes #3 and #4. The original program had not been completed but test results had eliminated roughly half the tonnage. The remaining portion would not have contained sufficient tonnage to make the area economical. The hole locations are shown on Figure 1.

B. Minnesota

1. General

Mr. E. Richard Randolph continued as Minnesota Resident Geologist during the year. In addition to Mr. Randolph's supervising the field programs and working with exploration matters on the various properties, he also assumed field supervision of the Wisconsin Project.

Temporary personnel consisted of Mr. Keith Roberts, temporary geologist, who completed his work the end of January, and seven foremen used for field work when they could be spared from the active properties.

Throughout the year Mr. Burton H. Boyum, Chief Geologist, visited the Minnesota offices and field location in connection with the exploration program, working with Mr. Randolph and the Minnesota Ore Committee.

2. Mesabi Range

a. L.O. #2960 - Haley Todd-NW-NE, S½ NE, Section 25,59-15

Two and three-fourths miles of additional line were brushed by foremen and 2¼ miles of magnetometer line were run at a cost of $275.00 or $2.07 per station. This data showed the previous magnetic interpretations, based on a reconnaissance survey to be coincident. It was seen that magnetics would be only of general aid to exploration. An E&A request in the amount of $8,000.00 for exploration drilling was approved at the December Ore Committee meeting.

b. L.O. #2967 - Longyear Estate - 5 Forties, Sections 23,24,60-13

This Land Offer is along the northern edge of the iron formation within Reserve Mining Company's domain. Several adjoining iron formation and non-iron formation forties appear to be available, but the land has not yet been examined. The property should lie on reasonably thick Lower Cherty Iron Formation.

c. L.O. #2969 - Great Northern Iron Ore Properties - 46 Forties in 58-18 and 59-18

These forties are scattered around a producing area and possibilities exist for retreat areas as well as some taconite reserves. Negotiations are continuing. One day was spent making a reconnaissance superdip survey of a portion of these lands. Figure 3.

d. McKinney Lake Area Lands - L.O.2918 - Trask
L.O.2928 - Holding
L.O.2934 - Wagner Blankenburg

No additional exploration was conducted in 1958.

e. L.O. #2959 - Kinross Farms

This land offer has a potential of 1,000,000 tons of possible direct shipping ore with a 2:1 stripping ratio. The Land Offer was declined due to the low natural iron content of the ore.

3. Northeastern Itasca County

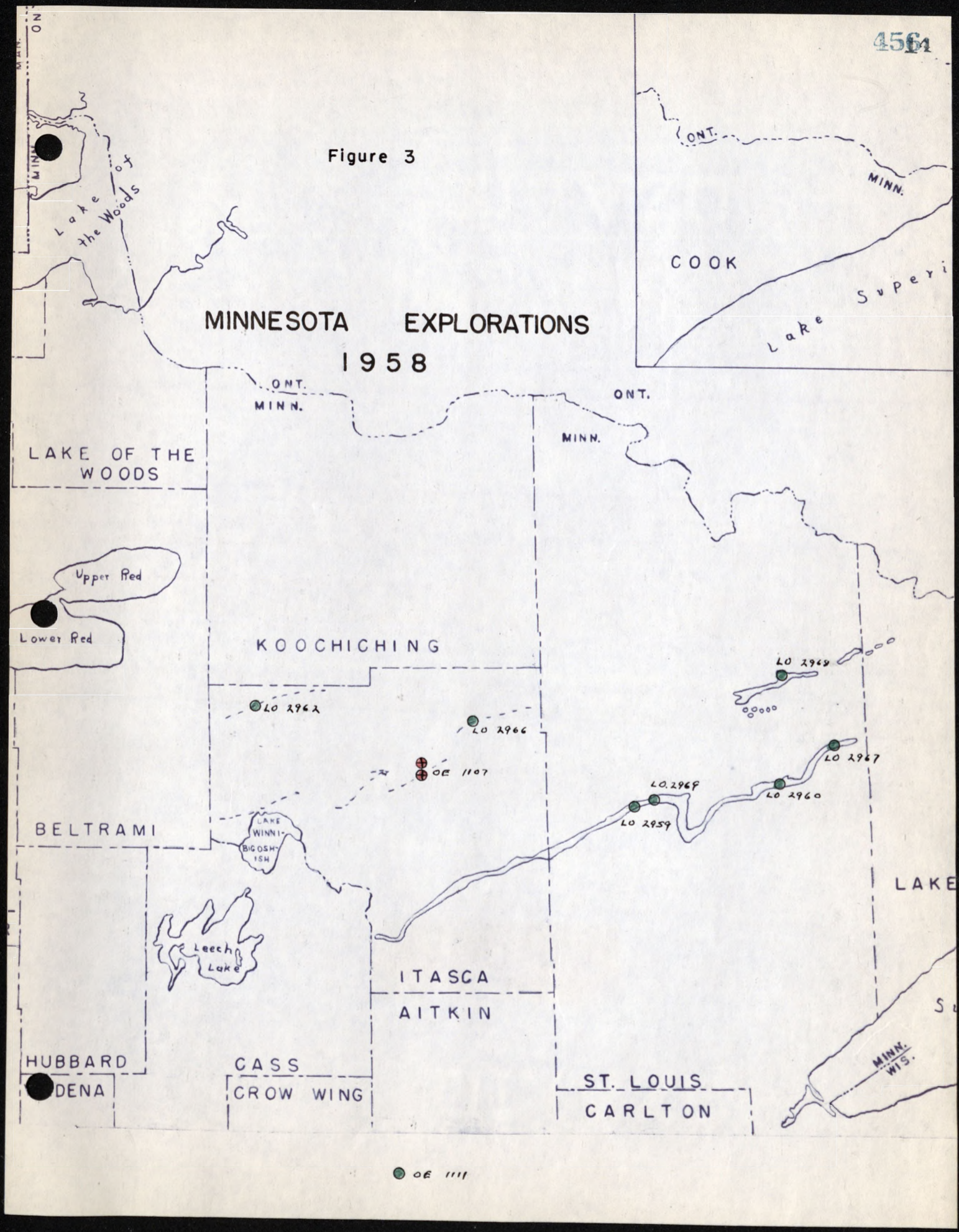
a. O.E.#1107

Foremen were used during the winter idle period to cut lines and run superdip survey. One and one-half miles of line were cut and 43 lines, or 32½ miles, of superdip survey were run. The cost was $483.00 or 57¢ per station.

Lease negotiations were culminated after 18 months of work. Drilling was finally able to begin in October on Bodel Corporation lands (Section 28,60-25) and on Pine Land Lumber Company property (NW-NW,Section 34,60-25). The surface was leased on a yearly wildcat exploration basis from Itasca County.

Diamond drilling consisted of BX angle holes, one each on two of the most prominent anomalies. Overburden footage was 378' and diamond footage was 336' by year's end and 684' by January 29, 1959 when the second and last hole was stopped. The vertical overburden depth averaged 120' and the primary rock materials were magnetic greenstone in Hole #1 and non-magnetic greenstone and argillite in Hole #2. Seven feet of magnetic iron formation were cored in Hole #1 and 24 feet of iron formation and associated rocks cored in Hole #2. Since these holes were in the most consistent and promising of the magnetic anomalies, much hope for developing a sufficient tonnage in this area has been abandoned.

Figure 3


MINNESOTA EXPLORATIONS
1958
ONT.
MINN.
COOK
Lake Superi
Lake of the Woods
LAKE OF THE WOODS
Upper Red
Lower Red
KOOCHICHING
LO 2962
LO 2966
OE 1107
LO 2968
LO 2967
LO 2960
LO 2959
BELTRAMI
LAKE WINNI-BIGOSH-ISH
Leech Lake
ITASCA
AITKIN
HUBBARD
CASS
CROW WING
ST. LOUIS
CARLTON
LAKE
MINN. WIS.
OE 1111

b. L.O.#2966 - Olson - W½-NW, Section 27, E½-NE,Section 28,61-24

Mr. Olson's land offer was a narrow (75' at measured spot) band of locally magnetic arenaceous silicate iron formation; and represented at least one of the mediocre magnetic highs on our superdip line nearby. The offer was declined.

c. L.O.#2962 - Reams - E½-NE¼, Section 29; W½-NW¼,Section 28,150-28

Mr. Reams represents the owner of four forties centered on a magnetic high near Island Lake. A possible concentration is suggested by the aeromagnetics as contrasted with the weak, narrow anomaly adjacent to it along the strike.

4. Other Minnesota Areas

a. L.O.#2968 - Canning - Section 10,62-14

Monograph 45, "The Vermilion Range", shows this area to contain continuous outcrop for a 500' width. Since C.C.I. records indicate that the specific area was not explored, inspection is in order, even though lands several miles away were examined and found to be of little value. Several properties along this side of the Vermilion iron formation can be assembled.

b. O.E.#1111 - East Central Minnesota

Mr. Wagner's options (L.O.2954) were returned to him at his request since Cliffs interest was nil during 1958 because of economic conditions. These lands were on or near the eastward extension of the magnetic anomaly over the South Range, east of Aitkin.

C. U.S. General

1. Wisconsin

a. General

Mr. E. Richard Randolph continued his duties as field supervisor of the Wisconsin Project. Field work was accomplished with the assistance of Mr. Keith Roberts, temporary geologist, and two foremen from Minnesota. The field work is broken down according to areas under the Outside Exploration numbers. Figure 4.

b. O.E.#1254 - Central Wisconsin General

Field work in this area is broken down into the various specific areas (below), except for the general seismic work conducted. Four spreads, or 16 shots, were made in various places in Juneau and Adams Counties at a cost of $350.00, or $21.87 per shot. The object was to get information on the thickness of the sand and soft rock overburden, which averaged from 200' to 300'.

Figure 4

WISCONSIN

OE 1254 INCLUDES

1 OE 1250
2 1251
3 1252
4 1253
5 1256
● DDH'S 1-6

MEC 7-23-57

1'. O.E.#1250 and #1251 - Adams County

Mr. Roberts ran 55,800' of magnetometer line at a cost of $175.00, or $1.10 per station. Mr. Lane ran 55,690' of magnetometer line at a cost of $75.00 or $0.27 per station.

2'. O.E.#1252 - Southern Juneau County

The area became the principal exploration area for 1958 because of the entry of the University of Wisconsin "Explorers" into the picture. Lane ran 31 miles of magnetics at a cost of $0.37 per station and Randolph added three miles of detail prior to drilling. Randolph and Mel Viant ran 10 miles of detailed gravity at a cost of $0.97 per station and ran a level survey over the same 10 miles at a cost of $1.69 per station.

Considerable effort in negotiating with the University of Wisconsin "Explorers" and the Juneau County Board was rewarded in July by the signing of an option and lease for exploration. This option and lease, approved in its principal parts by the State Attorney General's office, may serve as a model for future negotiations or even as a standard State option and lease form.

Much gravity information was obtained from the "Explorers". Field work and lease negotiations were in a stage such that drilling could start by August. Six holes were drilling for a total of 1273 feet of soft rock rotary drilling and 300 feet of hard rock diamond drilling. The cost of the drilling was $27,780.61, or $17.66 per foot. Much higher figures could have been generated by not making the extensive use of mud drilling techniques and the Joy 225 truck-mounted drill rig on this project. Drilling was completed in nine weeks, water procurement as the major problem.

All areas drilled had basic to moderately basic intrusives (diorite) as basement. Certain horizons were more dense and more highly magnetic than others. These horizons give rise to the gravity and magnetic anomalies which had previously been interpreted as being caused by sedimentary beds. Strong structural control apparently caused the intrusives to assume this form. The options were dropped.

3'. O.E.#1253 - Central Juneau County

Mr. Roberts ran 10,000 feet of magnetics in this area which adjoins O.E.1252. The magnetics were run at a cost of $1.04 per station.

4'. O.E.#1256 - Ward and Portage Counties

Much work was done in this area (which is not tied geologically to the Adams and Juneau County O.E.'s) by foremen. Several long magnetic anomalies were checked by crossings spaced at approximately one mile intervals. Seventy miles of traverse were completed at a cost of $350.00 or $0.23 per station. These anomalies remain interesting even though the Juneau County trend was not productive.

2. Missouri

Messrs. Boyum and Rex visited with members of the Missouri Development and Resources Division, and also with various principals of L. O. 3738, magnetic anomalies in Washington County. Plans were laid to pursue this Land Offer in 1959.

3. Idaho

Mr. Rex visited L. O. 3744 which is producing a minor amount of high density magnetite for the Atomic Energy Commission. A significant portion of the deposit is held by a copper mining company.

4. Wyoming

Ford and Fox, Consultants, carried on field work for Cliffs in Fremont and Niobrara Counties under O. E. 1262 and O. E. 1238. It is hoped that work can be resumed in these areas in 1959.

5. California

Mr. Rex examined two deposits in Southern California. Both were declined.

6. Nevada

Mr. Victor Kral, Resident Manager of the Ford Motor Company, while on a visit to Nevada, examined L. O. 3716. This offer was abandoned.

7. Arizona

Mr. Rex examined four land offers of alluvial deposits containing magnetite. All of these were declined.

8. New Mexico

Mr. Rex examined Land Offer 3736, a high grade magnetite deposit, near Socorro. It was offered to us through E. A. Young, Inc. Further field work is planned for 1959.

D. Canada

1. Ontario

a. Land Offer 3264-C - Nickel Lake

Mr. Andrew Tomasich of Virginia, Minnesota, acted as agent for Messrs. Cousinear, et al, of Fort Francis, Ontario, on this magnetic iron-formation property some eight miles due east of town. A reconnaissance survey with dip needle showed both encouragement and confusion as to the continuity of the iron-formation beds. A thorough survey by our Port Arthur office later showed insufficient mineable tonnage. The offer was declined.

b. Land Offer 3268-C - Otter Bay

The same group as above (L. O. 3264-C) then began work with dip needle and by marking claims on another similar deposit 15 miles NE of Ft. Francis along Otter Bay. Geologic inspection and a dip needle survey confirmed the long ($2\frac{1}{2}$ mi.) length of the formation, but also showed its width to be variable, broken by barren rock types, and generally too thin to develop mineable tonnage. The offer was declined.

D. Canada (cont'd)

c. O. E. 1419-C - Iron Bay Mines, Ltd.

This Bruce Lake Mine property, 30 miles south of Red Lake, Ontario, was opened for re-consideration during the fall of 1958. Reduced rail rates and the availability of natural gas and electrical power have changed the economic picture somewhat. A reconnaissance visit was made in December by Messrs. Pakkala and Randolph in company with Messrs. Mosher and Hains of Iron Bay Mines and Black of Cliffs of Canada. The material is magnetic cherty silicate iron-formation with good metallurgical characteristics. Because of the proximity of the lake to the deposit, necessitating long dikes or even draining of the lake, the property may become marginal even with a substantial reserve. Economic and engineering studies are continuing, particularly with regard to the water problem.

2. Quebec

a. O. E. 1244-C - Quebec Cobalt Property - J&L Steel Corporation

During the year The Cleveland-Cliffs Iron Company acquired an option on a half interest in the Quebec Cobalt project near Mount Wright in New Quebec. Drilling and concentration tests have been conducted and the data was processed in the Geological Department in Ishpeming. A trip was made to the property by Mr. Boyum in July.

b. L. O. 3244-C - Canadian Javelin - Jubilee Property

The Canadian Javelin Company offered Cliffs of Canada their Jubilee holdings near O'Keefe and Audrea Lakes in New Quebec. A visit was made to the property by Messrs. Bartley and Boyum in September. Negotiations terminated unsuccessfully.

c. L. O. 3261-C - Quebec, LaViolette County, Normand Lake Beach Sands

During January, Mr. E. L. Adams, of Los Angeles, offered a beach sand deposit in LaViolette County, Province of Quebec, to Cliffs of Canada, through Mr. B. H. Boyum. Preliminary test results indicated that a satisfactory product could be obtained at a -200 mesh grind. The final weight recovery was 3.49% and the concentrate contained 70.25% iron, 0.38% silica, with 1.96% titanium dioxide. Subsequent examination by R. W. Riedel showed that the sand deposit was very limited in extent and that it could not possibly produce sufficient concentrates to warrant development.

d. L. O. 3265-C - Quebec, Lake Matonipi Area, Monelle River - Anglo-Canadian Pulp and Paper Company

Anglo-Canadian Pulp and Paper Company had acquired a block of claims in the Monelle River area, southeast of Lake Matonipi, during the period when W. S. Moore and Pickands Mather were acquiring claims in the same general area. Anglo had conducted some preliminary exploration on their claims and had outlined a zone of hematite-bearing formation which they thought was of economic interest. Because of the reported unsatisfactory results obtained by Pickands Mather and the remote location of these claims, it was decided that the offer was not attractive and declined.

D. Canada (cont'd)

e. L. O. 3272-C - Quebec, Mount Wright Area, S. Zachs and M. Shawn

Mr. J. A. Retty, as agent for Messrs. Zachs and Shawn, offered Cliffs of Canada two groups of claims located on the south and west of Mount Wright, not too far distant from Quebec Cobalt, Bellechasse and Quebec Cartier properties. The information concerning these properties was very sketchy and after making a complete investigation of the published literature, it was determined that a great deal of exploration would be required to prove the existence of an economic deposit of iron-bearing material on the ground. It was quite evident that both Zachs and Shawn were hoping to dispose of their properties in order to further stock promotion and the offer was declined. The two properties will be reviewed again under our investigations in O. E. 1417-C and it may be that we will wish to re-enter negotiations in 1959.

3. Newfoundland

a. L. O. 3245-C - Newfoundland-Labrador, Julienne Lake, Canadian-Javelin

During the time of the re-examination of Land Offer 3244-C, Mr. W. H. Roxburgh, Chief Engineer of Canadian Javelin, requested that Cliffs of Canada consider their Julienne deposit at Julienne Lake, north of Lake Wabush. The suggestion was in the form of an offer. Mr. Roxburgh stated that Pickands-Mather and Company had completed nine diamond drill holes on the property for the account of Canadian Javelin and indicated that the property was available to Cliffs, should they so desire. Unfortunately, Mr. Roxburgh's optimism was not shared by Mr. Doyle and once again he thwarted all attempts at negotiation. The offer was declined.

4. Canada General - Operation Overthrust

During the entire year Mr. Robert W. Riedel, geologist, worked jointly for the Consolidated Mining and Smelting Company of Canada (COMINCO) and Cliffs of Canada from a base office in Port Arthur, Ontario.

Operation Overthrust is the name given to a massive project of geologic compilation, photo-geologic interpretation, and the production of aerial mosaics produced ans sold by the Hunting Technical and Exploration Services Limited of Toronto. The project covers an area of more than 370,000 square miles of pre-Cambrian Shield largely in Ontario and Quebec plus the major pre-Cambrian portions of Michigan, Wisconsin, and Minnesota. The Overthrust material consists of 42 aerial mosaics at four miles to the inch, 500 mosaics at one mile to the inch, and 500 transparent geological overlays at one mile to the inch.

One-half of Mr. Riedel's time was spent for Cominco and one-half for Cliffs as follows:

Cliffs Project - 3: This project was a study of the known iron deposits of Canada resulting in an evaluation of their relative ore potentials that possibly exist taking into consideration the gross economic factors that influenced each deposit. The report covering this work is entitled, "Geological Appraisal of the Known Iron Occurrences and Districts of Canada", and is dated March 3, 1958.

D. Canada (cont'd)

Cliffs Project - 4: The Title of the report covering this project effectively describes it; it is entitled "Iron Ore Production in the Dominion of Canada through 1956." The report is essentially a tabulation consisting of each production property by Province, its year of most recent production, the main type of material shipped and the total tonnage shipped from the property.

Cliffs Project - 5: This project was initiated at the close of 1958 and will be continued in 1959. It is to be a re-evaluation of the Project 3 data incorporating new geological and geophysical information, utilizing the Overthrust material which is now largely complete, and with an eye to the possible delineation of new areas for primary exploration. The study will also attempt to assess the economic feasibility of centralized treating of a number of locally scattered deposits of some appropriate type.

E. South America

1. Venezuela

In October Messrs. Eric J. Rex and B. H. Boyum visited a reported iron occurrence near Yaguaraparo brought to Cliffs' attention through Dr. Oswaldo DeSola. Some scattered iron showings were found but additional field work by the owners is required.

While in Venezuela Messrs. Boyum and Rex discussed the possibility of Cliffs joining with the Venezuelan Government to develop one or more properties in the Venezuelan National Reserve. A discussion was held with the Minister of Mines followed with a letter of proposed intent. In December, Messrs. H. S. Harrison, S. W. Sundeen and B. H. Boyum revisited Venezuela and continued the discussions with the Minister of Mines.

2. Colombia

In October Messrs. Rex and Boyum visited Colombia following their trip to Venezuela to investigate the magnetic beach sand deposit at Acandi in the Gulf of Derien in northwest Colombia near Panama. Samples were collected and indications obtained concerning the general geology and the possibility of finding ore in place.

3. Peru

A preliminary examination of the iron deposits of the Andes Iron Co., namely Hierro Magnate Caballo Uyu, and Pucara, was made by Messrs. S. W. Sundeen and B. H. Boyum.

Recommendations were made for an exploration and fact-finding option and, also, that an exploration subsidiary be formed with resident supervision by Cliffs personnel.

III. EXPLORATION DRILLING DIVISION - Gerald J. Anderson, Supervisor

A. General Highlights

The exploration drilling consisted of a very small program during the entire year. In January the program was reduced to a two-rig operation and in March was further reduced to a one-rig operation which continued through November. In December the crews were temporarily laid off until negotiations had progressed far enough in the Gladstone area so drilling could begin.

1. Experimental Drilling with Winkie Portable Diamond Drill

Interest in the Winkie portable diamond drill was first aroused by several articles in the Milwaukee papers about the drill and the company which produces it. During the late summer the inventor and the producer of the machine, Mr. Fred Wink, gave a brief demonstration of his drill at the Republic Mine. The demonstration indicated that this drill could definitely have an application at our open pit properties for grade control and for delineating geologic structures such as dikes, faults, etc. However, the demonstration was not sufficient to indicate the limits of the machine nor the drilling costs. A testing program was therefore conducted to determine these factors.

The testing indicated that holes up to 100' could be drilled with satisfactory core recovery. The average cost per foot was $7.09; however, 75% of the cost was for diamond bits. It is felt that the bit costs could be reduced substantially with further experimentation on design. I feel that Cleveland-Cliffs could definitely use one or two machines of this type for short hole testing where core is desirable and will so recommend when the economic picture looks better. The cost of the equipment is relatively small - the drill machine alone is $869 and the complete outfit including pump, rods, and core barrels is around $1500.

2. Comments on Table VII

During 1958 a concerted effort was made to reduce the diamond bortz inventory. It can be noted in Table VII that the bortz inventory on January 1, 1958 consisted of 41,868.42 Kts. valued at $211,571.40 and on December 31, 1958 consisted of 31,844,18 Kts. valued at $155,387.22. This was a reduction in inventory for the year of 10,024.24 Kts. valued at $56,184.18. If the total dollars are divided by the total carats, the value of the bortz disposed of is approximately $5.60/Kt. This low value per carat was due to the large amount of scrap bortz that was disposed of. It can be noted that during 1958 a total of 8,851.99 carats of scrap was used or sold for a total value of $20,775.64. The major portion of this material or 8,213.65 carats was sold to the Diamond Tool Research Company at $2.40 per carat.

B. Specific Details (Michigan)

1. Diamond Costs

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

TABLE V

PER FOOT COSTS OF DIAMOND BITS USED IN 1958 SURFACE DRILLING

Area	Hole Number	EX Ft.	EX Amt.	EX Per Ft.	BX Ft.	BX Amt.	BX Per Ft.	NX Ft.	NX Amt.	NX Per Ft.	Total Footage	Total Diamond Bit Costs	Average Cost/Ft.
Empire					(529	$2,487.57)					(529	$2,487.57)	
Section 19, 47-26	36				369	4,491.46	$7.77*				369	4,491.46	$7.77*
	37-38	74	$345.55								74	345.55	
Area Total	3 Holes	74	$345.55	$4.66							443	$4,837.01	$7.53*
Isabella													
Section 29, 47-26					(407	$2,085.43)					(407	$2,085.43)	
	5				75	3,083.97	$10.72*				75	3,083.97	$10.72*
	6				618	4,512.07	7.30	4	$22.41	$5.60	622	4,534.48	7.29
	7				535	3,038.16	5.68	13	131.25	10.10	548	3,169.41	5.78
	8				334	3,409.25	10.21	6	34.14	5.69	340	3,443.39	10.12
Area Total	4 Holes				1562	$14,043.45	$ 8.19*	23	$187.80	$8.17	1585	$14,231.25	$ 8.19*
Ogden													
Section 24, 47-27	3				209	$2,441.48	$ 5.30*				209	$2,441.48	$ 5.30*
	4				625	1,057.90	1.69	8	$33.78	$4.22	633	1,091.68	1.72
Area Total	2 Holes				834	$3,499.38	$ 3.66*	8	$33.78	$4.22	842	$3,533.16	$ 3.66*
Humboldt	9	28	$162.07	$5.79							28	$ 162.07	$ 5.79
Area Total	1 Hole	28	$162.07	$5.79							28	$ 162.07	$ 5.79
Republic	1-W to 3-W	61	$245.21	$4.02							61	$ 245.21	$ 4.02
Area Total	3 Holes	61	$245.21	$4.02							61	$ 245.21	$ 4.02
Wisconsin	1							55			55		
	2							12			12		
	3							21			21		
	4							48			48		
	5				169			17			186		
	6							6			6		
Area Total	6 Holes				169	$916.71	$5.42	159	$1,551.19	$9.76	328	$2,467.90	$ 7.52

*Includes that portion of hole drilled in 1957

2. Diamond Inventory - Hand Set

The following Table VI shows the distribution of carbon during the year 1958:

TABLE VI

DIAMOND INVENTORY (Hand Set), December 31, 1958

CARBON (Hand Set)

No. of Carats	Size in Carats	Value/Carat	Amount
162.88	2½ or Greater	$ 60.00	$ 9,772.80
86.63	1 - 2½	25.00	2,165.75
9.74	0 - 1	15.00	146.10
39.90	Ballas	5.00	199.50
299.15			$ 12,284.15

3. Diamond Inventory - Mechanical Setting

The following tabulation in Table VII shows the over-all distribution of all types of diamonds used and on hand during 1958:

TABLE VII

DIAMOND INVENTORY (Mechanical Setting), December 31, 1958

	SCRAP CARBON		SCRAP BORTZ		LONGYEAR		"F" GRADE		"R" GRADE		TOTAL	
	Cts.	Amount	Cts.	Amount	Cts.	Amount	Cts.	Amount	Cts.	Amount	Cts.	Amount
On Hand 1/1/58	265.53	$3,903.37	10,561.32	$18,629.72	175.90	$1,934.90	931.08	$13,035.12	29,934.59	$174,068.29	41,868.42	$211,571.40
Purchased 1958	-	-	-	-	-	-	94.66	1,325.24	4,745.59	45,669.88	4,840.25	46,995.12
Transfer	-	-	1,262.84	1,894.30	-	-	-	-	-	-	1,262.84	1,894.30
TOTAL	265.53	$3,903.37	11,824.16	$20,524.02	175.90	$1,934.90	1,025.74	$14,360.36	34,680.18	$219,738.17	47,971.51	$260,460.82
Used 1958 (loss)	-	-	8,851.99	$20,775.64	-	-	262.58	3,676.12	7,012.76	78,727.54	16,127.33	103,179.30
Scrap Credid	-	-	-	-	-	-	-	-	-	-	-	1,894.30
On Hand 12/31/58	265.53	$3,903.37	2,972.17	#251.62	175.90	$1,934.90	763.16	$10,684.24	27,667.42	$139,116.33	31,844.18	$155,387.22

DISTRIBUTION OF INVENTORY IN CARATS

	SCRAP CARBON	SCRAP BORTZ	LONGYEAR	"F" GRADE	"R" NEW	"R" USED	TOTAL "R"	"G" GRADE	TOTAL
Loose (Mfr's. Possession)	-	1,169.56	-	607.35	26.00	6,467.80	6,493.80	-	8,270.71
Loose (CCI Co. Possession)	265.53	-	-	-	-	6,044.11	6,044.11	-	6,309.64
Salvage Reports Pending	-	-	-	-	-	-	-	-	-
Bits in Stock or Issued		1,553.24	175.90	108.07	-	15,426.62	15,426.62	-	17,263.83
TOTAL	265.53	2,722.80	175.90	715.42	26.00	27,938.53	27,964.53	-	31,844.18

4. Summary of Surface Drilling

The Following Table VIII is a summary of the surface drilling including the cost analysis. Each of the areas is discussed separately under Section II.

TABLE VIII

SUMMARY OF SURFACE DRILLING - COST ANALYSIS

LOCATION	HOLE NUMBER	RIGS	OVERBURDEN	DIAMOND DRILLING	TOTAL	1ST CLASS ORE FOOTAGE	%	MET. ORE FOOTAGE	%	TOTAL COST "A"	COST/FT. "A"	TOTAL COST "B"	COST/FT. "B"
a. Marquette Range													
1'. Empire	36,37,38	CCI & Winkie	0	443	443	-	-	338	76.30	$8,697.24	$19.63	$9,715.95	$21.93
2'. Isabella	5,6,7,8	CCI	111	1585	1696	-	-	1406	82.90	21,916.43	12.92	22,628.55	13.34
3'. Ogden	3,4	CCI	33	842	875	-	-	801	91.54	18,075.39	20.66	18,368.35	20.99
4'. Humboldt	9	Winkie	0	28	28	-	-	28	100.00	350.86	12.68	454.36	16.43
5' Republic	1W, 2W, 3W	Winkie	42	53	95	-	-	53	55.79	785.82	8.16	955.82	9.93
b. Wisconsin													
1'. Juneau County	1,2,3,4,5,6	CCI	1245*	328	1573	-	-	-	-	27,210.79	17.30	27,780.61	17.66
TOTAL	19 Holes		1431	3279	4710	-	-	2626	406.53	$77,036.53	$16.36	$79,903.64	$16.96

*Includes Rock Bit Drilling

5. Plant Account

Table IX shows the comparative status with reference to depreciation of the Department-owned equipment.

TABLE IX

	Schedule A	Schedule B	Schedule C.	Total
December 31, 1957	$23,132.26	$302,914.21	$210,466.46	$536,492.93
December 31, 1958	23,132.26	302,914.21	211,906.46	537,952.93
Income from "Per Shift Charges"				
Total Year 1957			$ 69,417.55	
Total Year 1958			7,772.55	
Expenses from "Per Shift Charges"				
Repairs and Maintenance			5,192.43	
Depreciation			28,488.87	
Equipment		$ 25,448.82		
Rods		3,040.05		
Net Loss for Year 1958			25,908.75	
Total Equipment Book Value 1958			537,952.93	
Depreciation Reserve Fund 1958			305,089.33	
Depreciation Rods and Equipment above			28,488.87	
Net			$276,600.46	

C. Minnesota

The following Table X is a summary of Minnesota drilling

TABLE X

SUMMARY OF MINNESOTA DRILLING

	TOTAL FOOTAGE	COST "A"	COST/FT. "A"	COST "B"	COST/FT. "B"
1. O.E. 1107 E & A, CC-840	733	$9,744.93	$13.29	$10,538.58	$14.38
2. Canisteo					
a. Bovey	354	6,018.00	17.00	-	-
b. Well	234	2,063.13	8.82	-	-
3. Holman-Cliffs Bingham	539	9,163.00	17.00	-	-

Note: Bovey and Bingham lease holes were structural drilling, Henry Schulty Company, Contractor.

O.E. 1107 was diamond drilling, E. J. Longyear Company, Contractor.

Canisteo well was diamond drilling, Henry Schulty Company, Contractor.

IV. EXPLORATION OF MICHIGAN OPERATING PROPERTIES

A. Underground

Summary of Drilling

The following tabulation, Table XI, is a summary of underground drilling.

TABLE XI

UNDERGROUND DRILLING

LOCATION	HOLE NUMBER	RIGS	FOOTAGE DRILLED	1ST CLASS ORE FOOTAGE	%	TOTAL COST "A"	COST/FT. "A"	TOTAL COST "B"	COST/FT. "B"
Bunker Hill Group									
Bunker Hill Maas	90,91,92,93 114,115,116	Mine	683	215	31.5	$ 3,858.95	$ 5.65	$ -	$ -
Mather Mine "A" Shaft	446,462,470, 475,479,485, 492,493	CCI	3,773	614	16.27	44,744.58	11.86	54,983.10	14.57
Mather Mine "B" Shaft	454,456,457, 458,459,461, 462*,463,464, 465,466,467, 468,469,470* 471,472,473, 474,475*,476, 477,478,480, 481,482,483, 484,486,487, 488,489,490, 491,494-232' in December	Mine	8,984	3,457	38.47	69,411.18	7.72	91,414.29	10.18

*Holes drilled for Mather "A" under contract by Mather "B".

Cost "A" - Direct Drilling Charges
Cost "B" - Includes both direct and indirect charges

2. Geological Summaries of Underground Properties

a. Bunker Hill Group - Ted Engel,Jr., Geologist

Athens - Geological mapping of the mining development was the extent of geological investigation in the Athens property during the year. There were no significant changes in the expected structural outline as the result of this mapping.

Bunker Hill - There was no diamond drill program conducted at the Bunker Hill property during the year. Three short holes, totaling 230 feet, outlined a small section of ore occurring near the north end of the 10th Level conveyor drift for development purposes. A water drain hole was drilled from 10th to 12th Levels.

This drilling and the mapping of mining development revealed only minor changes in the expected structural outline.

Maas - Mapping incidental with mining development was the extent of geological investigation in the Maas property during the year.

Pioneer & Arctic - Three diamond drill holes, for development purposes were drilled in the Pioneer & Arctic property during the latter part of 1958. This drilling, and geological mapping incidental with the development, indicates a large irregular shaped mass of iron formation occurring within the previously outlined ore section west of the 2400 W. coordinate, resulting in a significant reduction in the ore reserves.

b. Cambria-Jackson Mine - Paul R. Bluekamp, Geologist

The reserves in the remaining structures at the Cambria Jackson Mine had been well outlined and delineated prior to 1958. Therefore, there was no diamond drilling or geological work conducted at this property during the year.

Extensive development was necessary to procure the remaining reserves and the economics of such development inhibited further operation of this property as of December 31, 1958.

c. Cliffs Shaft Mine - James P. Meyers, Mining Engineer

There was no drilling for hard ore underground or on surface at the Cliffs Shaft Mine in 1958. The geologic work conducted at the mine during the year was of a routine nature. Geological mapping underground was conducted and the geologic maps and sections were kept up to date in the office. The annual estimate of proven ore reserves and the attending reports were prepared and submitted. Various other reports and reserve studies were prepared and submitted throughout the year.

d. Mather Mine

1'. "A" Shaft - Lee Erickson, Geologist

The 1958 diamond drilling program for the Mather Mine "A" Shaft consisted of drilling eight holes, three of which were drilled under the supervision of the Mather Mine "B" Shaft. A total of 3,773 feet of drilling was completed, of which approximately 16% was first class ore. The diamond drill cost per foot for the year was $11.86. Of the year's drilling 20% was used to outline ore reserves above the 8th Level, and 80% to outline the reserves below the 9th Level. The average depth of the holes drilled to outline the reserves below the 9th Level was 875 feet with approximately 66% of the footage being drilled in hard hematitic iron formation.

As a result of mining and the revised method of calculating ore reserves, the 1958 estimate reveals a net decrease in ore reserves of 2,102,519 tons as compared to an increase of 3,462,678 tons in 1957. Included in the 1958 estimate is 411,009 net tons in Section 1,47-27, to be mined by the Mather Mine "A" Shaft.

Estimated Net Reserves as of December 31, 1957	10,350,519
Production January 1,1958 to December 31, 1958	823,860
Net Reserves as of December 31, 1958 by subtraction	9,526,659
Estimated Net Reserves as of December 31, 1958	7,424,140
Net Decrease in Reserves	2,102,519

Reserves on the 8th Level and above and between the 8th and 9th Levels were decreased, whereas reserves below the 9th Level were increased. The decrease in reserves, over and above the decrease due to mining operations, is the result of a revised method of estimating ore reserves. This revised method is necessary due to the present demand for a higher grade of ore. In general, the new method employed is as follows:

In determining ore estimates, consideration is given to the complex pattern of intrusives and their effect on mining operations. Mining experience has shown that developing and mining to within a distance of less than 15' from the hanging side of the intrusives causes excessive contamination of the product. Therefore, in outlining the ore areas, a 15' pillar is left adjacent to the hanging side of all the intrusives. The ratio of the volume of the intrusives and pillars to the volume of the total ore area, intrusives and pillars included, is the factor applied to all cross-sectional estimates. The factor presently used is 20.9% and is applied to the reserves both above and below the 9th Level.

Production for the year was 823,860 tons. Of the year's production, 11.25% came from the 7th Level, 56.07% from the 8th Level, and 32.68% from the 9th Level.

Diamond Drilling

8th Level - Four diamond drill holes were drilled from the 8th Level during the year. U.H.#479, located on the 11,900 W. section at S.3100, was drilled from the end of the 8300 cross-cut to a depth of 1,101 feet. This hole was drilled for the purpose of outlining ore reserves below the 9th Level south of the Jackson Fault* and west of the previous drilling on the 11,350 W. section. Approximately 60 feet of interbedded ore was disclosed and the hole bottomed in footwall formation. With the completion of U.H.#479 there is sufficient information to suspect that the Jackson Fault forks somewhere in the vicinity between the 11,350 W. and the 11,950 W. sections, and diverges toward the west. Major displacement is down to the south along the north limb with minor displacement,also down to the south along the south limb. U.H.#479 was collared between the two limbs of the fault and it is highly probable that since there was no enrichment of the iron formation above the interbedded ore, the hole also bottomed between the two limbs of the fault.

U.H.#485, located on the 11,950 W. section, was drilled from a drill station in the 8300 cross-cut at S.2470. This hole was drilled to investigate the area above the 8300 cross-cut south of a small east-west trending fault that has limited the ore body to the south. With the completion of this hole, it was concluded that there is no enrichment south of the 2450 S. coordinate in the area above the 8300 cross-cut. However, the hole intersected the north limb of the Jackson Fault, giving another point, and establishing the dip of the fault in this area. U.H.s #492 and #493,located on the 11,700 W.section, were drilled from the end of the 8400 cross-cut above the level and northeast of the Mather Fault so that mining could be planned in the area.

9th Level - One hole, U.H.#446, was completed from the 9th Level, -1325 sublevel, during the year. The hole, located on the 10,850 W. section, was drilled from a top-timber drift that was driven to the south off the end of the 9620 east drift. The hole was drilled to further outline the ore body below the 9th Level along the 10,850 W. section. Approximately 150 feet of ore was disclosed by the drilling.

10th Level - During the year three holes, located on the 10,600 W. section, were drilled from a top timber drift driven southwest off the end of the 10,900 "A" cross-cut. The drilling of these holes was supervised by the Mather Mine "B" Shaft. These holes were drilled to further outline the ore disclosed by the drilling on the 10,850 W.section, which is south of the Jackson Fault and west of the Mather Fault, and the drilling on the 10,400 W. section that is also south of the Jackson Fault but east of the Mather Fault. The present structural interpretation concluded from the drilling of these holes is as follows:

* Previously referred to as the E-W Fault.

10th Level (Cont.) - U.H. #462, drilled at an inclination of -90°, was collared south and west of the Mather Fault and south of the Jackson Fault. The hole bottomed between the two southerly dipping faults after crossing the Mather Fault. Approximately 232 feet of ore was disclosed in the hole. U.H.#470, collared at the same location but drilled at an inclination of -65° to the north, crossed the Mather Fault, cut 80 feet of ore built up along the Jackson Fault, and bottomed in footwall on the north side of the Jackson Fault. U.H.#475, also collared at the same location, was drilled to the south at an inclination of -65°. It is probable that this hole did not intersect the Mather Fault but bottomed southwest of it, and so the 140 feet of ore encountered correlates with the ore disclosed by the drilling on the 10,850 W. section.

Subsidence Studies

General - Microseismic activity at the Mather Mine "A" Shaft subsidence area was recorded daily throughout the year. From the recordings and other related information, it was concluded that a small amount of subsidence did take place but at a depth or distance far enough from the recording geophones that only the stronger of the microseisms were detected.

During the year, two attempts were made to repeat the velocity survey conducted in 1957. Both failed due to the fact that the shot holes were no longer to ledge and it was impossible to get energy through the overburden to the recording geophones.

The pin grid system, set up by the Engineering Department over the surface area of suspected cave, was checked regularly throughout the year. The vertical displacement of the steel pins was very minor and gave no indication of surface subsidence.

Weirs and flumes, located in the main level drift water trenches, were checked regularly and readings taken. The flow of water from the various levels was calculated and recorded. By this means any surface water entering the mine should be readily detected.

On all main levels, dam facilities are present so that dams can be constructed at any time to control water entering the pump stations at the shaft.

Microseismic Activity

Microseismic activity over the old 5th and 6th Level workings was recorded throughout the year from geophones located in surface subsidence holes D.D.H.#65, D.D.H.#68 and D.D.H.#69. D.D.H.#65 and D.D.H.#68 are located over the 5th Level workings and D.D.H.#69 is located over the 6th Level workings. The geophone in D.D.H.#68 is positioned north of the Mather

Fault and the phones in D.D.H.s #65 and #69 are positioned south of the Mather Fault.

The highest microseismic count for the year was in March for D.D.H.s #65 and #69, and in July for D.D.H.#68. It is of importance to note that the microseismic count from D.D.H.#65 was 200 in January, increased to 562 in March and decreased to 4 in July; while the count from D.D.H.#69 increased from 200 in January to 546 in March and decreased to 19 in July. During this same period the count from D.D.H.#68 reached a maximum of 45 in July with only 1 recorded in March. Therefore, it is concluded that during the first part of the year there was definite movement on the south side of the Mather Fault. It is highly possible that the reason for the lack of noise recorded from D.D.H.#68 is due to the fact that the geophone is located north of the fault and the fault zone attenuated the propagation of the microseisms. It is further concluded that the areas under test are again stable as the December count was: #65 - 9; #68 - 3; #69 - 38. The maximum counts recorded are extremely low as compared with areas of subsidence that have been studied elsewhere.

Since there was no indication of air movement, either in or out of the subsidence holes under study, plus the fact that the water levels remained fairly constant in all three holes, it is considered that the Mather "A" subsidence area has remained relatively stable during the year and the area of cave is still in excess of 950 feet from surface.

Velocity Survey

During the year two attempts were made to repeat the velocity survey conducted in subsidence Hole D.D.H.#65 in 1957. Both attempts were unsuccessful because the shots could no longer be fired at ledge contact. The shot holes had partially caved in due to previous shooting and therefore, it was impossible to get energy through the overburden and to the geophones with the amount of explosive permissible to use. It is necessary that additional shot holes be drilled before a repeat velocity survey can be conducted, or work can continue with the interval velocity study recommended in 1957. Furthermore, because of the extremely high velocity of diorite obtained by the 1957 survey, it would be impractical to reinterpret any reflection work that has been done until the stability of this velocity is determined. It is hoped that the economic condition in the year ahead will be such that continued work can be carried out along these lines.

2'. "B" Shaft - Paul R. Bluekamp, Geologist

Diamond Drilling - A total of 9,288' of diamond drilling was done in 1958; 1,640' were drilled for Mather "A" under contract to

Mather "B". This footage was cut in 36 holes, 19 on the 9th Level, 9 on the 10th Level, and 4 holes each on the 7th and 8th Levels. The main objectives in the drilling program were:

1. Detailing ore in 73-B, 74-C and 89-A Blocks.
2. Outlining most of the ore on the 9th Level.
3. Outlining some 10th Level ore.
4. Outlining ore and structure below the 10th Level to provide information for laying plans for the 11th and 12th Levels.

7th Level - Four holes were drilled to outline 73-B and 74-C Blocks prior to development. A hanging wall encroachment was found which cut out some tonnage from the two blocks. Also, some lean areas were found within the ore in 73-B Block, which will necessitate very careful mining and possibly elimination of development in some parts of the block.

8th Level - Three holes were drilled to outline the south end of 89-A Block. Large horizontal encroachments of iron formation were found coming in from the hanging wall to the south. Therefore, no more development was planned for this area. One hole was drilled on the 10050-W section to determine the thickness of the ore directly below 8th Level.

9th Level - Two holes were drilled up to the 8th Level for ventilation raises. Seventeen holes were drilled to outline the 9th Level ore. These holes nearly complete the outlining of the 9th Level ore - only the west end remains to be outlined. Several encroachments of lean material were found in the 9th Level ore. The largest of these encroachments comes in from the hanging wall and cuts into the ore body at 8800-W and continues westward to the Cambria Fault at 9100-W. A second large encroachment is found between the Jackson Fault and the ore body and extends from 8750-W to 9050-W. It is about 200' high and averages about 50' in thickness. These encroachments have lowered the ore estimate somewhat and have caused some changes in development plans. The general size and shape of the 9th Level ore body, from the shaft pillar to the Cambria Fault, remained about the same as expected.

10th Level - The 10th Level drilling was divided into two phases: the first phase was the drilling of three holes on the 10600-W coordinate to outline ore and structure for Mather "A". This drilling was financed by Mather "A" and the results of this drilling will be in the Mather "A" annual report.

The second phase was the outlining of ore and structure below the 10th Level. On the 8550-W section, the footwall leaves the Jackson Fault

just above the 10th Level and dips southward at about -20°. At Dike 27, the footwall is displaced downward about 70' and continues to the Cambria Fault. There is a considerable amount of ore lying on the footwall between the Jackson and Dike 27 Faults. In the trough formed by the junction of Dike 27 and the Cambria Fault, another body of ore was found. On the west side of the Cambria Fault, the footwall is displaced upward about 80' and there appears to be a body of ore where the footwall is intersected by an east-west dike at 3400-S. On the 9300-W section, the footwall leaves the Jackson Fault just above the 10th Level and dips southward at about -28°. It is displaced downward 100' by Dike-Fault 28 and continues to another large east-west dike at 3520-S. Between these latter two dikes, an orebody of considerable size has been indicated. Close correlation between these sections has not been possible as yet due to the fact that they are separated and displaced by the Cambria Fault.

Ore Reserves - The net ore reserves reported to the Tax Commission on December 31, 1958, were 10,902,542 tons, a decrease of 2,059,038 tons from the previous year. The reserves were decreased due to a recognition in the estimate that some ore is unrecoverable as the result of higher grade requirements, and the reduction by diamond drilling. indicated

Subsidence

As in the previous year a considerable amount of time was spent on subsidence studies in an attempt to trace the progress of the cave at Mather Mine "B" Shaft. At the end of last year the cave was estimated to be slightly over 1200' from surface. As a result of work done in 1958 it is estimated that the cave is over 1000' from surface.

Microseismic counts were recorded daily from the six geophones located in holes #153, #167 and #168. The counts indicated very little cave activity and are listed by months as follows:

	#153		#167		#168		
	800'	1000'	600'	800'	725'	900'	Total
January	87	19	32	30	124	2	294
February	337	38	3	3	135	1	517
March	21	19	27	9	62	2	140
April	43	41	14	179	72	127	476
May	32	18	8	10	157	5	230
June	77	83	37	13	94	8	312
July	115	193	15	17	146	33	519
August	10	1	11	2	61	27	112
September	7	1	45	23	25	1	102
October	29	11	1	3	7	3	54
November	21	6	55	68	5	2	157
December	9	3	3	6	18	2	41
	788	433	251	363	906	213	2954

Time interval tests were made monthly between Holes #153 and #167; these tests also indicated that the cave was advancing very slowly. The results of these tests are as follows:

	800'	1000'
January	48.85	60.96
February	48.875	61.335
March	49.03	66.24
April	48.03	62.75
May	48.90	63.48
June	48.71	64.91
July	48.70	67.895
August	48.75	65.32
September	48.68	65.52
October	48.20	66.44
November	48.17	67.56
December	48.21	68.72

Pumping

Pumping of the North Jackson underground workings continued through 1958 at an average rate of 239 G.P.M. This is the same rate as last year. The purpose of this pumping is to dewater the old workings which lie over present mining areas.

At Partridge Creek three out of the four pumps burned out during the year. Pumping was continued with one pump operating at 300 G.P.M. The water table, which had been drawn down 19'9" rose to 10'0" during the time necessary to install one additional pump.

B. Open Pit

1. Geological Summaries of Open Pit Properties - Donald R.Lukkari,Geologist
James W. Villar, Geologist

a. Humboldt

With the temporary termination of operations at the Humboldt Mine early in the year, the emphasis of the Geological Work was switched from operations to future plans and pit development. A stripping program which would prepare the pit for expanded annual production of approximately 6,000 tons of concentrate was proposed. Another study was made of the possibility of by-passing a large portion of the lean fine-grained iron formation occurring along the footwall contact within the central area. In order to offset this depletion of reserves, development of the Weber Lease would be necessary. Information of a reliable nature is absent in this area and therefore it will be necessary to diamond drill before proceeding with this scheme of development.

Diamond Drilling

One short diamond drill hole was attempted at Humboldt as part of the Winke test program. The hole was started at -20° into the pit face at N. 5,600 and 8,720 W. The hole hit a void or crack at 27 feet. Cave material blocked any further progress. An attempt was made to cement the hole but it was unsuccessful and the hole was abandoned. The hole was in lean, fine-grained iron formation up to 27 feet.

b. Republic Mine

A detailed mapping program of all new exposures resulting from stripping and mining operations was initiated during the year. Included in the program was a remapping of all exposures in the mine area including the silicate complex in the footwall. With the completion of this program, a new set of geological sections was drawn up. East-West sections at 100 foot intervals were completed covering the proposed pit area. These sections will be used for mine planning and for new estimates.

A short super-dip survey was completed in the Park City area during the year. A test line was run along the highway where the contact between the silicate iron formation and the oxidized iron formation is fairly well established. The magnetic profile along this line showed a sharp break at the contact. A second profile was made along the 1,000 foot West coordinate but no sharp break was detected that would indicate the contact. It was hoped this line could be checked by the Winke test drilling program but unfortunately the overburden was too deep.

Diamond Drilling

Three holes were attempted at the Republic Mine as part of the Winke test drilling program. The first two holes were abandoned because of excessive overburden. The third hole was located at 1200 feet North and 55 feet West on an exposed outcrop. This is on a faulted portion of the formation which projects into the hangingwall. The hole intersected 53 feet of medium to coarse-grained specular hematite. It proved that this fault block does contain ore.

V. LAND OFFERS AND OUTSIDE EXPLORATIONS

A. Land Offers

During 1958 the Geological Department continued to process various mineral Land Offers submitted to the Company. In 1958 a total of 63 new Land Offers was submitted by individuals or companies. Other Land Offers were carried on a current status from previous years. They are not included in the tabulation of the distribution of the six principal geographical areas tabulated below; nor in the graphs (Figure 5) in the following page:

Area	No.	% of Total
1. Michigan	3	4.8
2. Minnesota	4	6.3
3. Canada	20	31.7
4. U. S. General (incl. 1 Alaska)	27	42.9
5. South & Central America	7*	11.1
6. Africa	2	3.2
	63	100.0%

* Includes 1 in Mexico

As in 1957, most of the new Land Offers in 1958 were in the U. S. General category (this includes 1 in Alaska). The total number of new Land Offers dropped to 63 from the previous year's total of 100. The number of South and Central America (including Mexico) Land Offers increased from 2 to 7. Those originating in Canada dropped to just over one-half of the previous year. Michigan and Minnesota continue to decline in number of new Land Offers.

The geographical distribution of the Land Offers is shown on the attached maps, Figure 6, United States, and Figure 7, Canada.

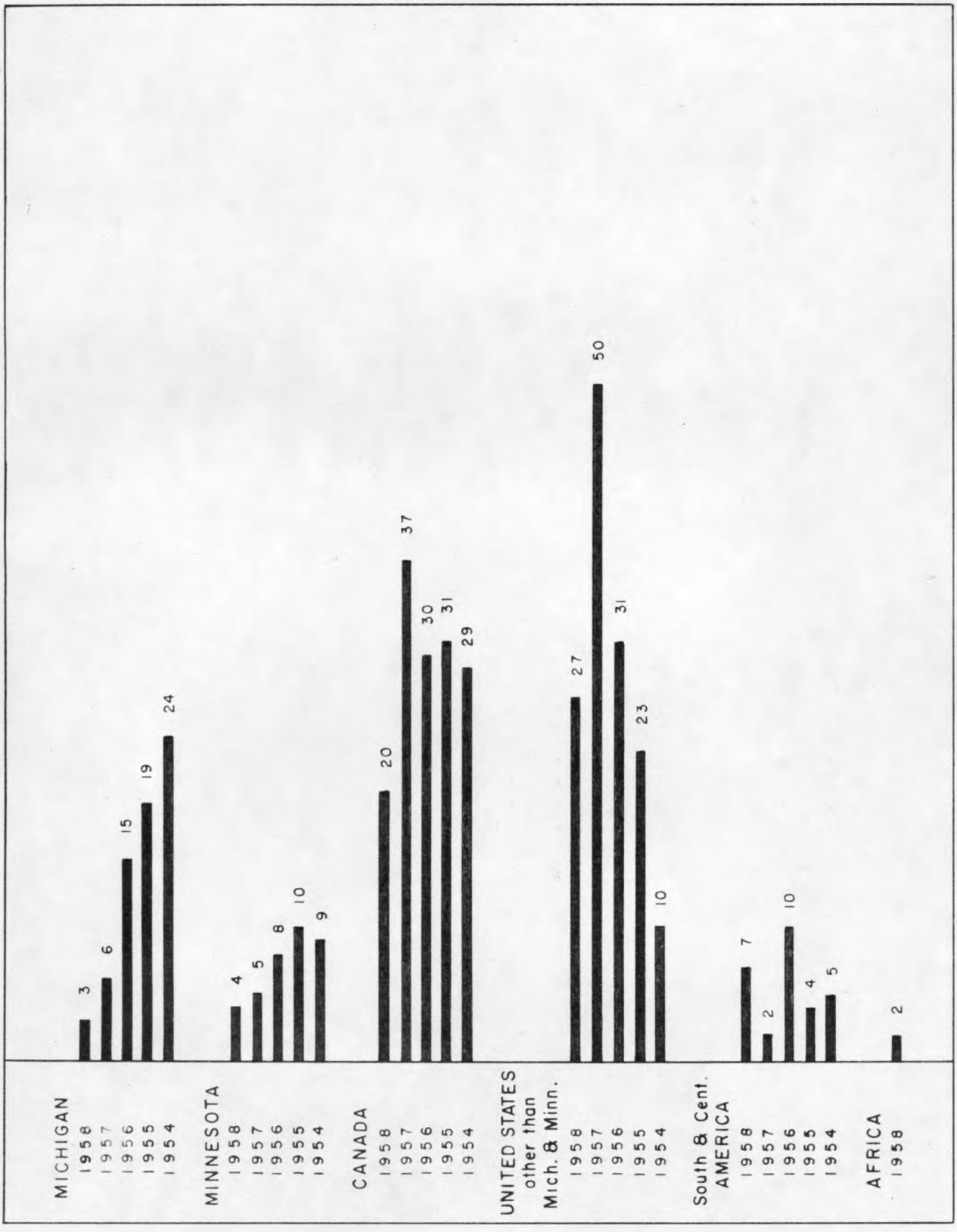
The following tabulation lists the expenditures:

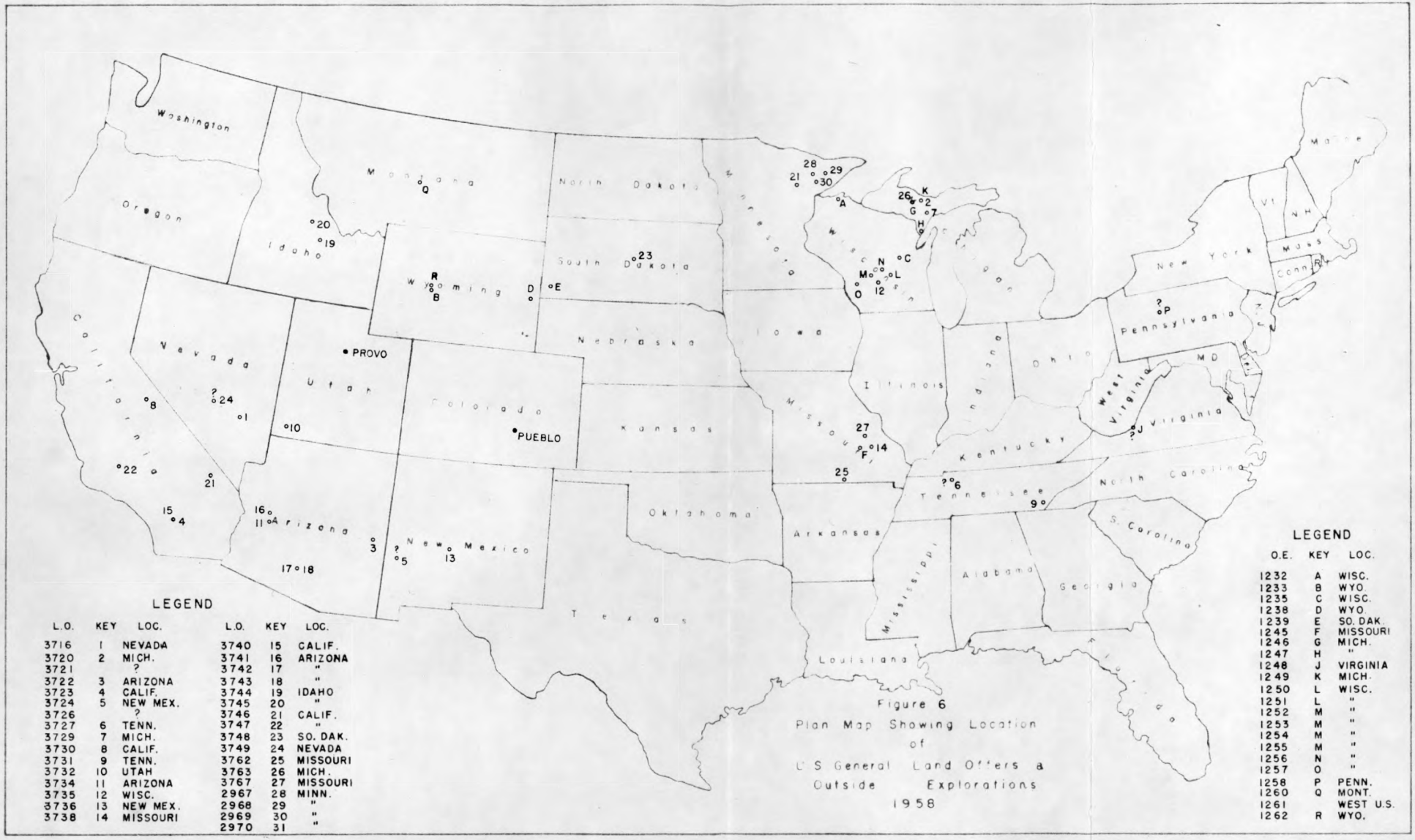
Area	1958	1957
1. Michigan	$ 1,377.29	$ 2,150.23
2. Minnesota	2,074.83	8,978.78
3. U. S. General	10,137.50	20,563.68
4. Canada	1,114.27 (US orig.)	6,439.47 (US orig.)
	9,825.75 (Can orig.)	64,715.73 (Can. orig.)
5. Africa	128.48	-
6. South and Central America	6,447.75	5.00
Total	$31,105.87	$102,852.89

Note: Above charges for Canada do not include Albanel Minerals, Ltd., or Quebec Cobalt.

Figure 5

GRAPH SHOWING RATE OF MINERAL LAND OFFERS 1954 - 1958 incl.





LEGEND

L.O.	KEY	LOC.	L.O.	KEY	LOC.
3716	1	NEVADA	3740	15	CALIF.
3720	2	MICH.	3741	16	ARIZONA
3721		?	3742	17	"
3722	3	ARIZONA	3743	18	"
3723	4	CALIF.	3744	19	IDAHO
3724	5	NEW MEX.	3745	20	"
3726		?	3746	21	CALIF.
3727	6	TENN.	3747	22	"
3729	7	MICH.	3748	23	SO. DAK.
3730	8	CALIF.	3749	24	NEVADA
3731	9	TENN.	3762	25	MISSOURI
3732	10	UTAH	3763	26	MICH.
3734	11	ARIZONA	3767	27	MISSOURI
3735	12	WISC.	2967	28	MINN.
3736	13	NEW MEX.	2968	29	"
3738	14	MISSOURI	2969	30	"
			2970	31	"

Figure 6

Plan Map Showing Location of U.S. General Land Offers & Outside Explorations 1958

LEGEND

O.E.	KEY	LOC.
1232	A	WISC.
1233	B	WYO.
1235	C	WISC.
1238	D	WYO.
1239	E	SO. DAK.
1245	F	MISSOURI
1246	G	MICH.
1247	H	"
1248	J	VIRGINIA
1249	K	MICH.
1250	L	WISC.
1251	L	"
1252	M	"
1253	M	"
1254	M	"
1255	M	"
1256	N	"
1257	O	"
1258	P	PENN.
1260	Q	MONT.
1261		WEST U.S.
1262	R	WYO.

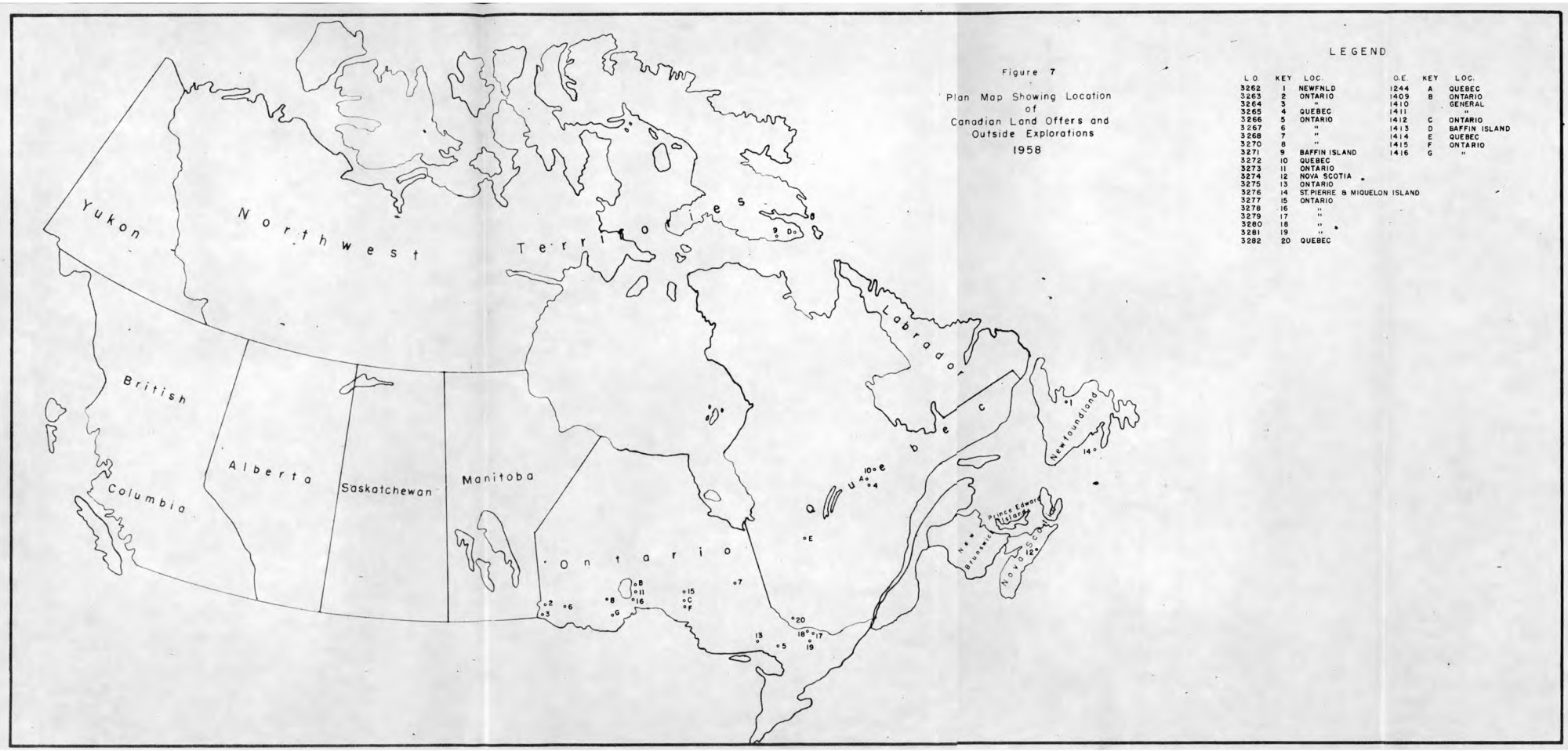


Figure 7

Plan Map Showing Location of Canadian Land Offers and Outside Explorations 1958

LEGEND

L.O.	KEY	LOC.	O.E.	KEY	LOC.
3262	1	NEWFNLD	1244	A	QUEBEC
3263	2	ONTARIO	1409	B	ONTARIO
3264	3	"	1410		GENERAL
3265	4	QUEBEC	1411		"
3266	5	ONTARIO	1412	C	ONTARIO
3267	6	"	1413	D	BAFFIN ISLAND
3268	7	"	1414	E	QUEBEC
3270	8	"	1415	F	ONTARIO
3271	9	BAFFIN ISLAND	1416	G	"
3272	10	QUEBEC			
3273	11	ONTARIO			
3274	12	NOVA SCOTIA			
3275	13	ONTARIO			
3276	14	ST. PIERRE & MIQUELON ISLAND			
3277	15	ONTARIO			
3278	16	"			
3279	17	"			
3280	18	"			
3281	19	"			
3282	20	QUEBEC			

B. Outside Explorations

We use the term "Outside Explorations" for mineral areas and deposits which are not actually offered to Cliffs, but are studies as:

1. Deposits or areas for later acquisition on the basis of their potential.
2. As a source of valuable information.

The distribution of Outside Explorations new in 1958 is as follows:

Area	No.	% of Total
1. Michigan	3	8.2
2. Minnesota	-	-
3. U. S. General	19	51.4
4. Canada	9	24.1
5. South and Central America	4*	10.8
6. Miscellaneous (Greenland)	2	5.5
	37	100.0%

* - Includes 1 in Mexico

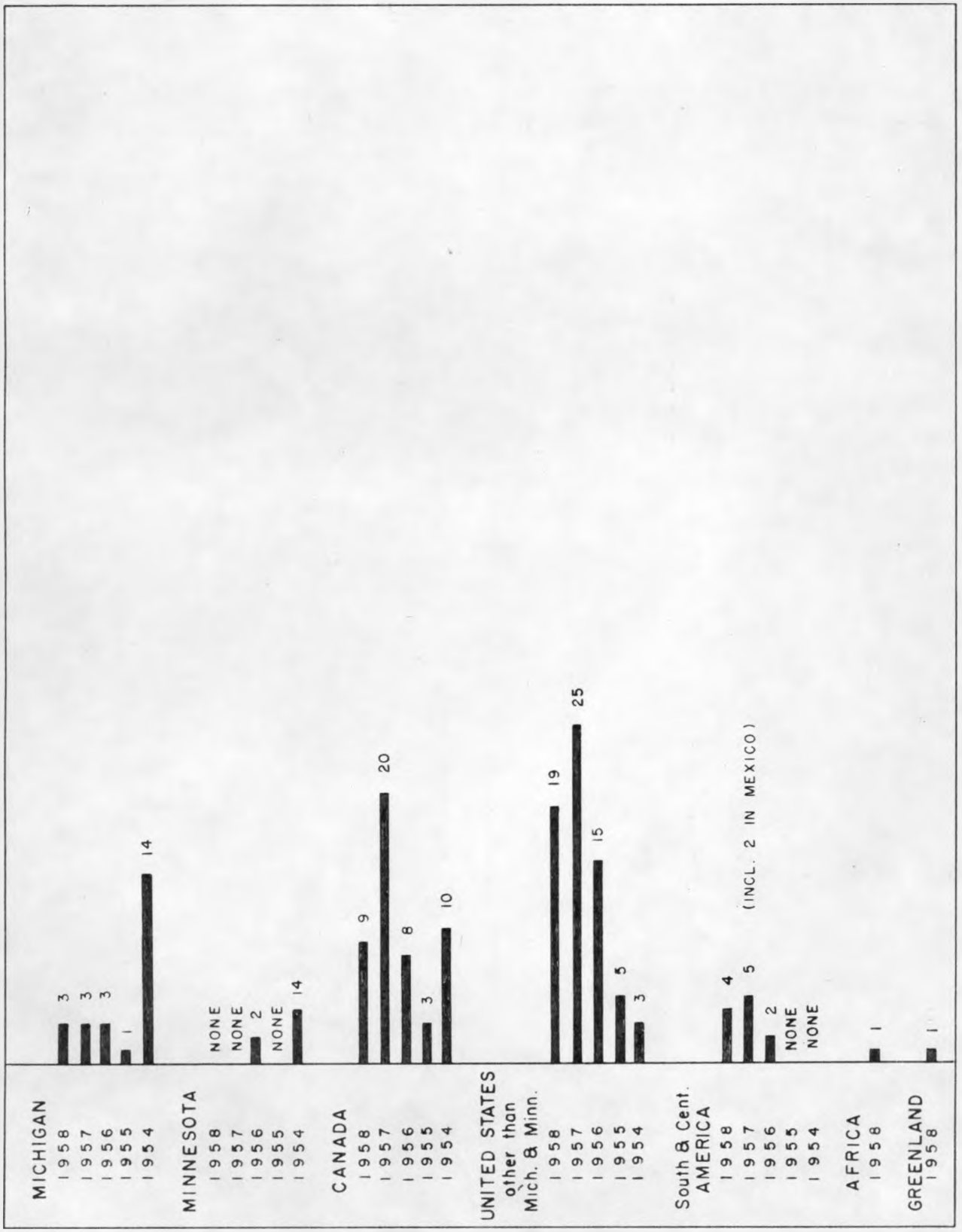
The total number of Outside Explorations decreased in 1958; however, the rank of the various geographical areas remained the same. Canada showed the largest decline. The 1958 total for Canada is less than one-half of that of 1957 (Figure 8).

The following tabulation shows the expenditures on Outside Explorations by the six principal geographical locations:

Area	1958		1957	
1. Michigan	$ 426.50		$15,545.03	
2. Minnesota	1,787.47		12,665.04	
3. U. S. General	20,592,60		41,706,51	
4. Canada	1,376.05	(US orig.)	4,090,40	(US orig.)
	23,085.05	(Can.orig.)	56,105.19	(Can.orig.)
5. South & Central America	1,116.47		2,201.59	
6. Miscellaneous (Greenland)	106.67		-	
Total	$48,490.81		$132,313.76	

Note: The above charges for Canada do not include Albanel Minerals, Ltd. or Quebec-Cobalt.

GRAPH SHOWING RATE OF OUTSIDE EXPLORATIONS 1954 - 1958 incl.



VI. MICROSCOPY - Tsu-Ming Han, Mineralogist

During the year the Microscopy Section of the Research Laboratory continued to be shared by Geology and Metallurgy. The projects completed for the Geological Department during 1958 were as follows:

A. Michigan

1. New Richmond Project

A microscopic investigation of core specimens and samples from drill holes at the New Richmond area was conducted. This investigation is part of the low-grade ore program which covers the study of lithologic, mineralogic, and textural variations of the materials and their effects on MOC-concentration. The results of the investigation indicated that the concentrate grade is largely determined by primary factors involving grain size, shape, hardness, distribution, composition, and association of the iron oxides. With a 325 mesh grind, the more favorable materials appeared to be coarse-grained martite-chert and medium-grained martite-chert, and the less favorable materials appeared to be fine-grained martite-chert, goethite-chert, and earthy hematite-chert.

2. Tilden Fire Tower Area

A similar type of investigation was also conducted on the iron formation of the Tilden Fire Tower area. The iron formation in the area consists of three principal lithologic types: (1) Martite-chert, (2) martite-bearing jaspilite, and (3) martite-bearing clastics. Metallurgically, the martite-chert and martite-bearing clastics are more favorable for MOC-concentration than the martite-bearing jaspilite. A comparison of the Tilden and New Richmond iron formation shows that the martite-chert predominates at the New Richmond and the martite-bearing jaspilite predominates at the Tilden. It is concluded that the iron formation at the Tilden is not as desirable for MOC-concentration as the iron formation at the New Richmond.

B. U. S. General

1. Arizona

Land Offer 3734 - A sample of black sand from an area near Wickenburg, Arizona, was submitted by Mr. Eric Rex, Project Supervisor, for microscopic investigation. The sample appears to be a desirable material for magnetic concentration. A high phosphorus magnetic concentrate containing 66.85% iron, 2.92% silica and 0.89% titania with more than a 50% weight recovery has been produced by direct magnetic concentration. The phosphorus, silica and titania can be reduced considerably by grinding the concentrate to minus 150 mesh and then reconcentrating magnetically.

2. California

Land Offer 3708 - A magnetic concentrate from a beach sand sample from Redondo Beach, California, was submitted. The product analyzed 62.2% iron, 2.59% silica, and 7.30% titania with a 32.91% iron recovery. It was concluded that the 7.30% titania in the concentrate is attributed to ilmenite ($FeOTiO_2$) and ulvospinel ($2FeOTiO_2$). These minerals are so intimately intergrown with the magnetite that they are practically mechanically inseparable.

3. Nevada

Land Offer 3716, Hanley Group - A magnetic concentrate from a sample collected near Hawthorne, Nevada, was microscopically and chemically investigated. The object of the investigation was to determine why the concentrate contains only 55.2% iron, 1.2% silica, and 0.092% titania and to find the additional constituents present. The study revealed that the low iron content in the magnetic concentrate was attributed to the ionic substitution of iron in the magnetite by magnesium, manganese, and aluminum.

4. Wisconsin

O.E. 1252 - Three drill core specimens from Diamond Drill Holes #1, #5 and #6 in Juneau County, near Necedah, Wisconsin, were received for petrographic identification. The preliminary study revealed that the material from D.D.Hole #1 is altered gabbro, from D.D.Hole #5 probably intensely altered quartz-diorite, and from D.D.Hole #6 olivine-gabbro. Since these rocks are present in the same general area, they could have been crystallized from a single parent magma through magmatic differentation.

C. Canada

O.E. 1244-C - Quebec, Canada - Mr. Burton H. Boyum, Chief Geologist, requested that a suite of iron-bearing specimens from Quebec Cobalt be microscopically studied. The specimens were classified as follows: (1) martite ore, (2) specular hematite ore, (3) specular hematite-magnetite ore, and (4) magnetite ore. Based on the ore size, ore size ranges, and mineralogy of the materials, the first three ore types appeared to be more suitable for high tension separation. A highly desirable concentrate with a high iron unit recovery can be achieved by a minus 48 mesh grind. The last ore type appeared to be more suitable for direct magnetic concentration. An acceptable concentrate containing less than 10% silica with a relatively low iron unit recovery can be produced by a minus 100 mesh grind.

E. Special Research

During the year a laboratory and microscopic examination was conducted on the direct shipping ores from the Bunker Hill, Maas, Mather Mine "B" Shaft, and the Cascade East End. The purpose of the examination was to compare the physical characteristics of the Cascade ore with that of the mines now in operation. Results of the investigation revealed that the Cascade ore is essentially made up of more than 60% non-porous martite and less than 40% soft earthy hematite. Physically, it is a fairly hard, porous and granular ore having a maximum moisture content of 9%. The study revealed that the Cascade will yield an ore with a lower moisture content than that of the Bunker Hill, Maas or the Mather Mine "B" Shaft, and will have a structure resembling that of the Maas Mine.

ILLUSTRATIONS

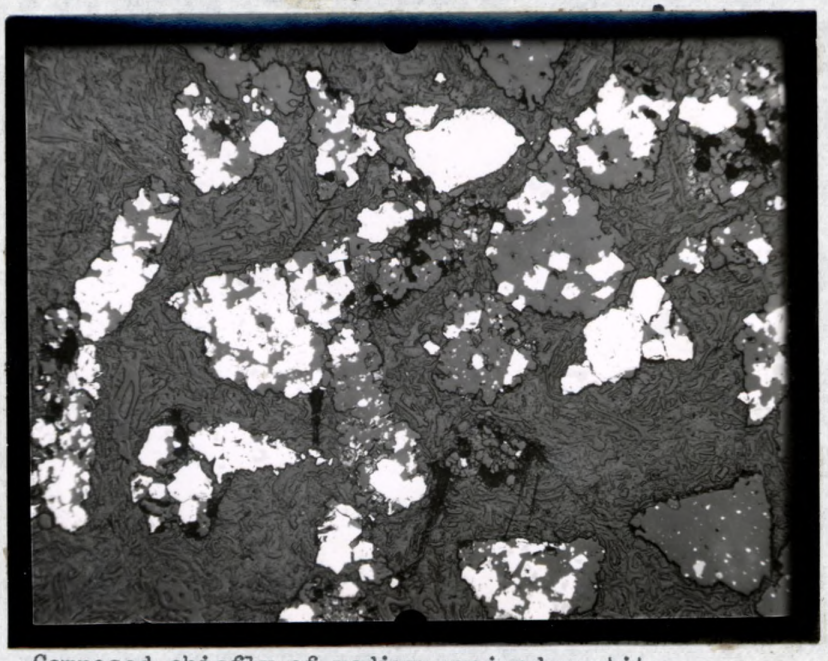


Plate 1
Sample No. RH-1-A
New Richmond

Composed chiefly of medium-grained martite-chert with subordinate amounts of coarse-grained martite-chert and chert. 100x. Produced concentrate analyzed: 65.10% Fe, 7.91% SiO_2 with 93.58% iron unit recovery.
Martite, white; and chert, grey.
Polished Section No. 1772. Photomicrograph No. 1086.

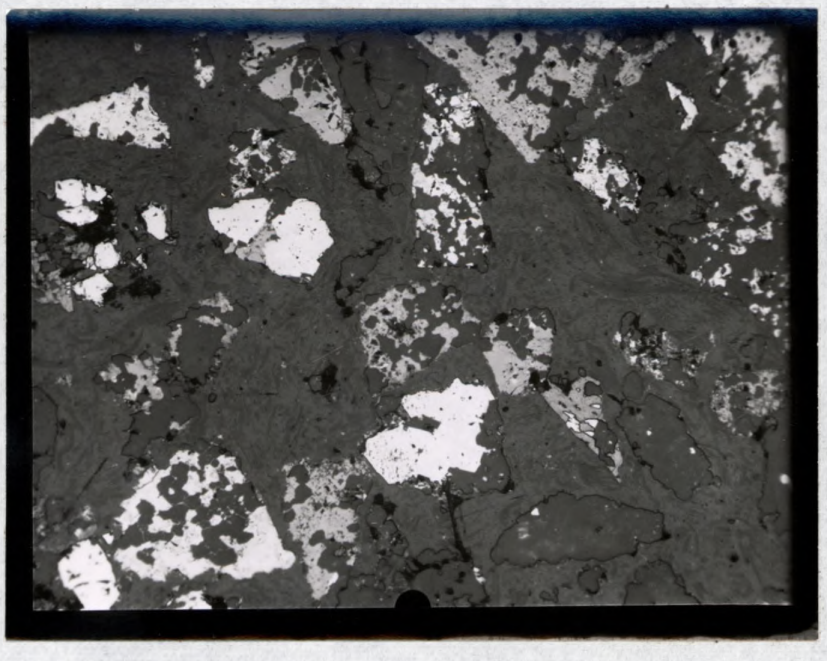


Plate 2
Sample No. RH-5-C
New Richmond

Composed mainly of goethite-chert, hematite-chert, chert, hematite-martite-chert, coarse-grained martite-chert, and fine-grained martite-chert. 100x. Produced concentrate analyzed: 58.13% Fe, 17.10% SiO_2, with 92.70% iron unit recovery. Martite and hematite, white; goethite, greyish white, and chert, grey.
Polished Section No. 1786. Photomicrograph No. 1105.

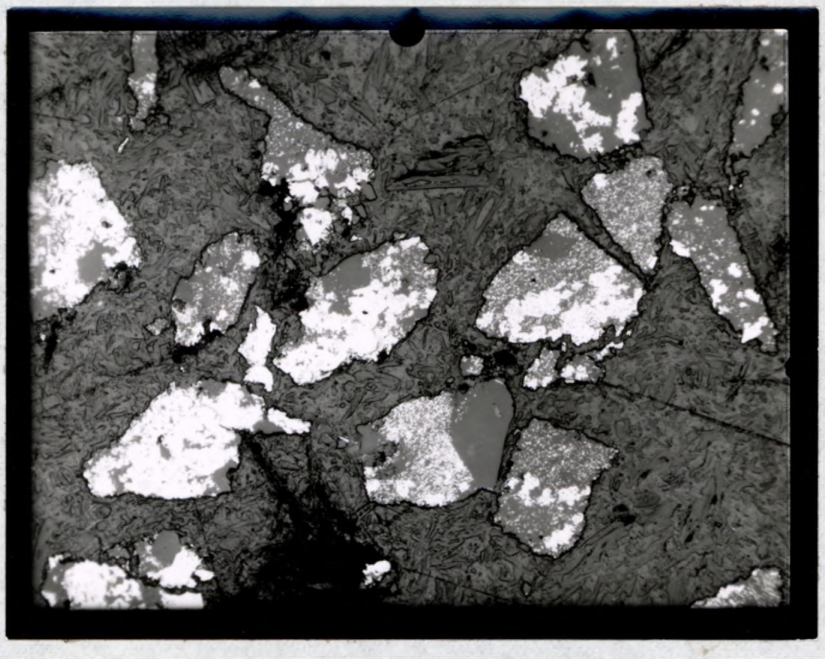


Plate 3
Sample No. T-197-I
Tilden

Composed of particles of martite-bearing hematite-chert with clastics. Produced concentrate analyzed 62.90% Fe, 16.75% SiO_2, with 94.66% iron unit recovery. Martite and hematite, white; chert and quartz, grey.
Polished Section No. 1843. Photomicrograph No. 1146.

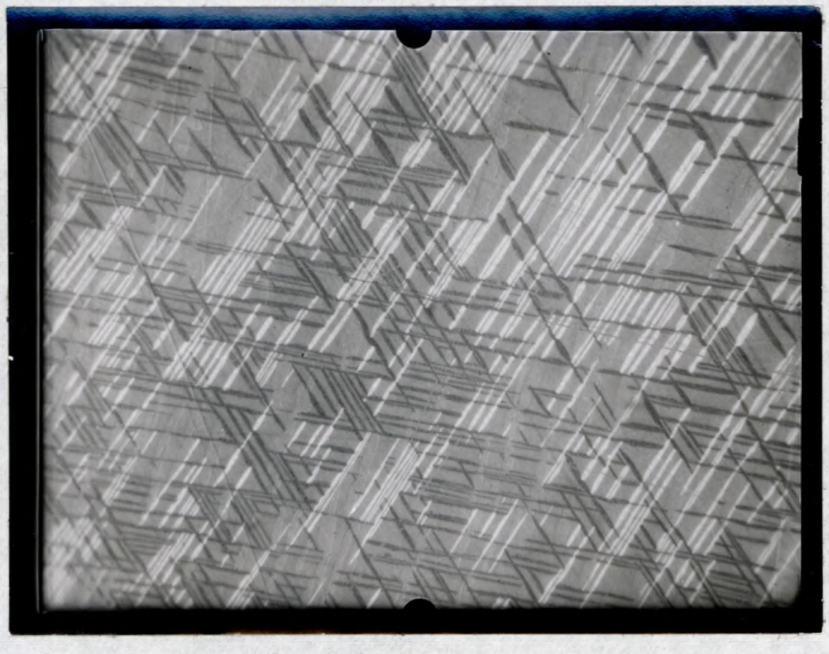


Plate 4
Land Offer 3708
Redondo Beach,
California

Oriented ilmenite plates in magnetite host. 500x. Crossed Nicols. Magnetite, grey; and ilmenite, white and dark grey.
Polished Section No. 984. Photomicrograph No. 1136.

Plate 5
O.E. 1244-C
Quebec Cobalt,
Quebec, Canada

Specular hematite-magnetite ore. Note the relationships between specular hematite, partly oxidized magnetite, and gangue. 80x. Specular hematite, white; magnetite, greyish white; gangue, dark grey; and cracks, black.
Polished Section No. 1977. Photomicrograph No. 1245.

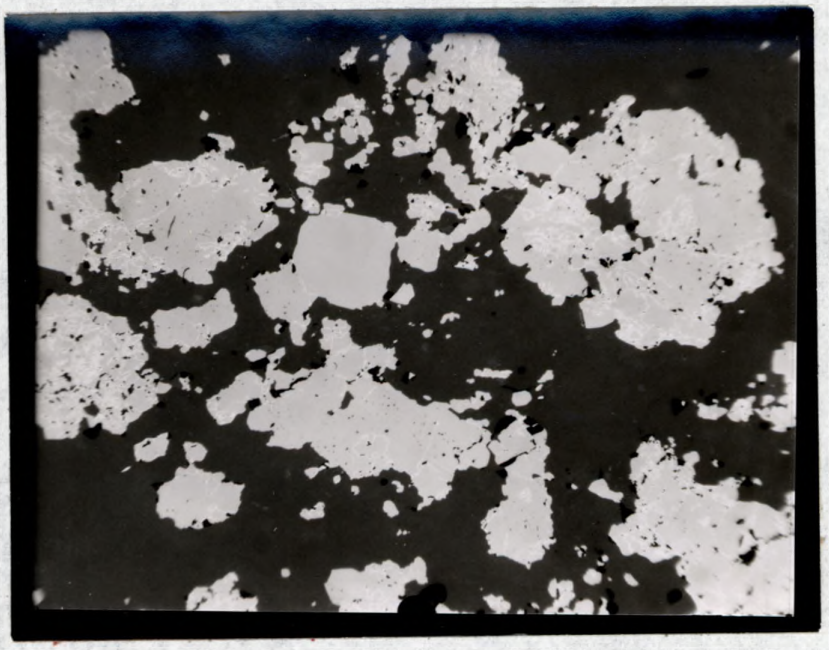


Plate 6
O.E. 1244-C
Quebec Cobalt,
Quebec, Canada

Magnetite ore. Note the granules of fine-grained slightly oxidized magnetite clusters unevenly distributed in a quartz rock. 80x. Magnetite greyish white; hematite, white; and quartz, dark.
Polished Section No. 1980. Photomicrograph No. 1248.

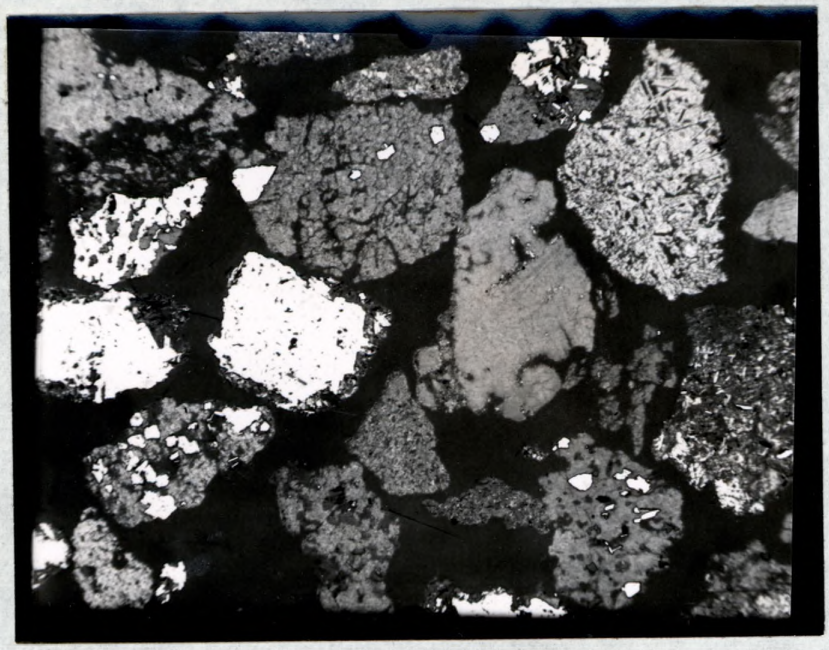


Plate 7
Bunker Hill
Soft Ore
Marquette, Michigan

-65 mesh +100 mesh ore particles of the Bunker Hill North orebody. Note the nature of disintegration of earthy hematite particles by impregnating solution. 100x. Martite, white; earthy hematite, grey; and impregnating material, dark grey.
Polished Section No. 1960. Photomicrograph No. 1162.

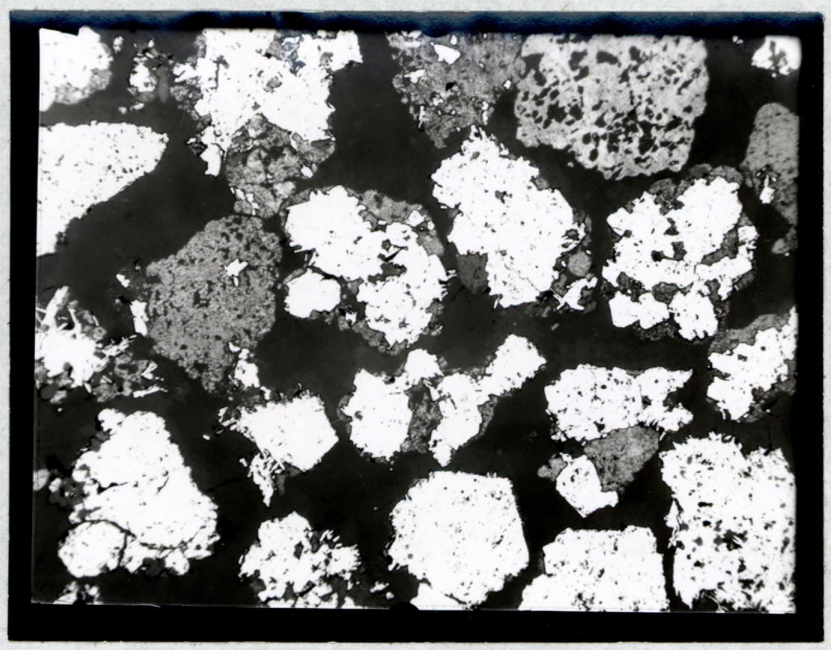


Plate 8
North Orebody
Cascade East-End
Michigan

-65 mesh +100 mesh ore particles of the Cascade North orebody. Note the abundance of martite and its relationship to earthy hematite. Martite, white; earthy hematite, grey; impregnating material and gangue dark.
Polished Section No. 1864. Photomicrograph No. 1166.

VII. OTHER DEPARTMENTAL HIGHLIGHTS

A. Laboratory and Microscopic Examination - Cascade East End

During the year a laboratory and microscopic study was undertaken in an attempt to establish the moisture content and physical characteristics of the Cascade East End Direct Shipping Ore using the operating properties as a control. For this study samples were obtained from drill core specimens selected from drill holes in the main ore bodies of the Bunker Hill, Maas and Mather Mine "B" Shaft. Several holes were used in each orebody in an attempt to obtain a representative sample. All of the holes that encountered ore at the Cascade East End were used. The laboratory tests have brought out the following results:

1. Screen analysis of the various ores indicate that the iron in the Cascade ores tends to concentrate in the fractions finer than 48 mesh and coarser than 325 mesh, while the iron in the Maas, Mather Mine "B" Shaft and Bunker Hill south ores tends to concentrate in the size range between 150 mesh and 400 mesh. The Bunker Hill north ore shows slight variation and the iron concentrates are in the size range between 65 mesh and 400 mesh. This indicates a slightly coarser material that may be an added factor in improved structure at the Cascade.

2. The absorption and evaporation tests show that the Cascade ore is more readily saturated with water and more easily dried than those from the Bunker Hill, Maas and Mather Mine "B" Shaft.

3. The saturation (maximum absorption) test reveals that the Cascade ore contains less water at saturation than the ores from the other properties.

The microscopic examination has revealed the following salient features:

1. Texturally, the ores are composed of (1) martitic particles, (2) fine-grained hematite, (3) clusters of hematite needles, (4) hematite with fibrous gangue, and (5) microscopic botryoidal hematite. Based on these variations, three ore types may be distinguished which are (a) the Bunker Hill ore type, (b) the Maas-Mather ore type, and (c) the Cascade ore type.

2. Physically, the martitic particle and the fine-grained hematite are comparatively hard and compact while the other particles are soft and relatively porous. The ratio between these two types of material appears to be the most important factor in determining ore structure and moisture content. Other factors being equal, the greater the compact/pourous particle ratio, the better the ore structure and the less the moisture content. The ratio of the compact/porous particles in the Cascade north ore is considerably greater than any of the other ores.

3. Although the ratios in the Cascade ores are greater than those in the Mather Mine "B" Shaft ore, due to the difference in mineral relationship, the ore structure of the Cascade ores may not be quite as good as that of the Mather Mine "B" Shaft ore. Nevertheless, it will probably be lower in moisture content.

On the basis of the tests it may be concluded that the Cascade ore is essentially made up of more than 60% non-porous martite (48 to 325 mesh) and less than 40% soft porous earthy hematite. The latter is commonly composed of gangue minerals. Physically, it is a fairly hard porous and granular ore having a maximum moisture content of not more than 9%.

B. Papers and Publications

1. Departmental Reports

During the year 1958 the following reports were prepared and issued by the Department under the following headings:

a. General Exploration Reports

Report No. 42 - Recommended 1958 Exploration Policy - Burton H. Boyum

b. Geology & Mineralogy

Report No. 30 - Mineralographic Examination of a Magnetic Concentrate Produced from a Beach Sand Sample, Redondo Beach, California - Tsu-Ming Han

Report No. 31 - Miscroscopic Investigation of Core Specimens and Samples from DDH No. 4, Section 23; DDH No's. 4, 6,7, Section 25 and Holes No's. 55 and 56, Section 26, at Tilden Fire Tower Area - Tsu-Ming Han.

Report No. 32 - Laboratory and Microscopic Examination of Direct Shipping Ores from Bunker Hill, Maas, Mather Mine "B" Shaft and the Cascade East-End - Tsu-Ming Han and Donald R. Lukkari.

Report No. 33 - Microscopic Examination of Some Samples from Sections 27 and 39, T. 19, R.6E. - Tsu-Ming Han.

c. Geophysics

Report No. 15 - Progress Report Refraction Seismic Survey, Cascade East-End - Lee Erickson.

d. Diamond Drilling

None

e. Ore Reserves

Report No. 11 - Cliffs-Shaft Mine First Class and Second Class Ores - James P. Meyers.

f. Subsidence

None