A STUDY OF THE
MINERALOGIC AND MAGNETIC CHARACTERISTICS
OF METAMORPHOSED IRON FORMATION
FROM THE JULIAN DEPOSIT
WABUSH LAKE AREA, LABRADOR

~~A~~ Thesis ~~Presented~~
by
William ~~Broderick~~ B Blakeman
to
The Faculty of the Graduate College
of
The University of Vermont
In Partial Fulfillment of the Requirements
for the Degree of Master of Science

May, 1968

Accepted by the Faculty of the Graduate College, The University of Vermont, in partial fulfillment of the requirements for the degree of Master of Science, specializing in Geology.

Thesis Committee: Chairman

Advisor

Raymond W. Grant

Dean, Graduate College

ABSTRACT

The Julian iron deposit in the Wabush Lake area of Southwestern Labrador contains metamorphosed quartz iron oxide facies of the Precambrian Wabush Lake Iron Formation. The deposit lies in an area dominated by two fold systems, 12 miles south of the Grenville front. The axes of the folds in the older system trend to the northeast, generally parallel with the front zone; those of the younger, superposed system trend to the northwest, across the zone. The rocks in the vicinity of the deposit contain metamorphic mineral assemblages in the almandine amphibolite facies. The deposit contains the Wapussakatoo quartzite, Huguette schist and the Wabush Lake Iron Formation. Structurally, these formations represent a northeast trending syncline overturned to the northwest. The principal minerals are: quartz, hematite, less than 3% magnetite, limonite-goethite, manganese oxides and relicts of a probable iron silicate. Hematite occurs as specularite and granular hematite. Eight ore types have been recognized based on mineralogic and physical differences. Microscopic examination of polished sections shows that granular hematite is a mixture of martite and amorphous hematite without recognizable grain boundaries. Martite may have formed from magnetite during the late stages of metamorphism and amorphous hematite may be the product of post metamorphic solution, mobilization and redeposition of the Fe_2O_3 formerly existing as martite. Widespread occurrence of martite and amorphous hematite in amounts of up to 100% of the total Fe_2O_3 in some samples indicates that magnetite was formerly a major constituent. Polished sections exhibit evidence of oxidation and leaching. Ground magnetic responses over the deposit up to 18,000 gammas above background are due to unusual magnetic characteristics of hematite rather than magnetite content. Magnetic susceptibility tests indicate variable susceptibilities for the iron minerals, thus variations in ground magnetic responses are not a direct function of quartz-iron mineral ratios. Susceptibility tests show specularite to be from two to four times as susceptible as martite-amorphous hematite. A direct correlation appears to exist between the susceptibility of concentrates and outcrop ground magnetic values at the extremes of the respective scales. Concentrates containing less than 22.5% specularite have low magnetic susceptibilities and represent outcrops with values of less than 6000 gammas. Appreciable quantities of specularite in outcrops probably account for higher ground magnetic responses.

ACKNOWLEDGEMENTS

The writer wishes to thank his employer, Canadian Javelin Limited, Ottawa, Ontario, for the permission and financial support to undertake this study, as well as Javelin's Chief Geologist, Dr. D. M. Knowles and Vice President of Engineering, Mr. W. H. Roxburgh, for their technical advice and encouragement. The writer is also indebted to other members of Canadian Javelin's staff who participated in various phases of the field work on the Julian Iron deposit and whose prior contributions are incorporated in several technical reports and maps of the property which have been utilized as background material for this study.

In addition to those listed above the writer wishes to thank the following people: Mr. Leo Desrochers, Canadian Javelin's draftsman, for the excellent maps and drawings which accompany this thesis; Doctors R. K. Doten, R. S. Stanley and R. W. Grant of the Geology Department, University of Vermont, for their invaluable assistance, advice and encouragement; Mr. H. A. Preston and Mr. R. Becker of the University of Vermont Instrumentation and Model Facility for their advice and efforts in constructing the magnetic susceptibility meter utilized in this study.

TABLE OF CONTENTS

TABLE OF CONTENTS

CHAPTER PAGE

III MINERALOGIC INVESTIGATIONS (Cont'd)

APPENDICES

APPENDIX PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER I

Introduction

Several deposits of metamorphosed iron formation exist in the Wabush Lake area of southwestern Labrador. Most of these deposits consist of quartz, specularite and up to 30% magnetite, but two of them consist predominantly of quartz and hematite. This thesis is concerned with the mineralogy and magnetic aspects of the Julian iron deposit, which is one of the latter type.

The Problem

The Julian deposit contains three different varieties of iron oxide, i.e., specular, granular and earthy hematite; plus accessory limonite-goethite and extremely minor amounts of magnetite. In spite of the virtual absence of magnetite, strong magnetic responses are obtained with a magnetometer over localized parts of the deposit and these responses appear to be related to the mineralogy in an unusual manner. Ground magnetic surveys indicate that a general relationship does exist between stratigraphic and/or mineralogic units and the responses obtained by magnetic instruments.

Hematite, (Fe_2O_3), the primary ferric constituent, is by definition essentially non magnetic, and ordinarily one would have difficulty in picking up even .05 millimeter sized particles with a hand magnet. It is easily demonstrated, however, that grains of specularite from this and other deposits of metamorphosed iron formation in the Labrador Trough, may be activated or picked up with a hand magnet. The current study will investigate this phenomenon.

The problem therefore, is twofold; (1) to determine the nature and origin of the various varieties of iron oxides and other minerals in the ore and; (2) to determine the nature of the stratigraphic, mineralogic, and magnetic relationships.

Previous workers (Pickands Mather, 1957) have determined that there is less than 3% magnetite in diamond drill core samples, and Javelin personnel have never identified magnetite in hand specimen. The variations in the intensity of magnetic responses obtained at different locations, therefore, are probably not attributable to an appreciable quantity of magnetite in the deposit. Although the responses obtained here do not compare quantitatively with those recorded on deposits containing magnetite, variations as high as 18,000 gammas* have been recorded on this property.

---

*gamma (γ) unit of magnetic field intensity equal to 10^{-5} oersteds. Total magnetic field of the earth is approximately .5 oersted - Dobrin (1952)

Because there are obvious variations in the intensity of magnetic responses in different localities, and these localities frequently provide suitable outcrops of a recognized mineralogic-stratigraphic unit, the following questions arise:

1. Is there a direct relationship between the magnetic susceptibilities and mineralogy of selected samples?
2. Is there a definite relationship between the magnetic susceptibilities of selected samples and the outcrops which they represent?
3. Is there a definite relationship between the amounts of different iron oxides and non magnetic minerals in selected samples and the outcrop ground magnetic values?

If the inherent magnetic nature of the ferric iron alone is responsible for these variations, and if this is constant for all samples of the iron oxides then the ground magnetic variations may reflect only the quantitative relationship between the ferric iron and quartz (or any other nonmagnetic material). In contrast, there may be distinct differences in the magnetic character of the ferruginous constituents from one location to another so that given the same ferric iron/quartz ratio for any two localities, the observed instrument responses may be completely different.

This study investigates these problems in order to increase the state of general geologic knowledge about the deposit, and to explain (or show) why the Julian deposit is mineralogically and magnetically different from other deposits in the area. It involves the microscopic examination of one hundred specimens in polished section and magnetic susceptibility measurements of the ferruginous fractions of twenty-five of these specimens.

Procedures

The major procedures followed in this thesis are:

1) Selection of 100 ore samples, sub-divided so that they represent an approximate quantitative distribution of seven mineralogic types found in the Julian deposit.
2) Preparation and mounting of the samples in Bio Plastic for polished section study.
3) Grinding and polishing.
4) Microscopic examination of each polished section to determine the mineralogy, inter granular relationships, order of genesis, and relative abundance of the minerals based upon a 500 point count per section.
5) Selection of the unused split of twenty-five samples which had been studied in polished section and collected from outcrops in areas which have significant differences in their ground magnetic characteristics as exhibited

by an isomagnetic map.

6) Crushing, pulverizing and separating the ferrous and ferric iron and determining the percentage of magnetite and/or iron filings (from processing) in each of the twenty-five samples.

7) Performing magnetic susceptibility tests on hematite, limonite-goethite, and pyrolusite fractions.

8) Collection and interpretation of data.

Location and Access

The Julian deposit is situated on a peninsula between the Northern ends of Wabush and Julienne Lakes in South-western Labrador, Newfoundland at latitude 53° 05' North and longitude 66° 56' West (Figure 1).

It is approximately 15 miles north of the iron mining towns of Wabush and Labrador City, and 200 miles North of the port of Seven Islands, Quebec. The deposit may be reached by vehicles via an 18 mile provincial road from Wabush and Labrador City.

Geography-Physiography

The Wabush Lake area is situated on the Labrador Plateau, which ranges in elevation from 1500 to 1700 feet. Lakes, streams and swamps are abundant, and low rounded hills rise 200 to 500 feet above the general table land. The

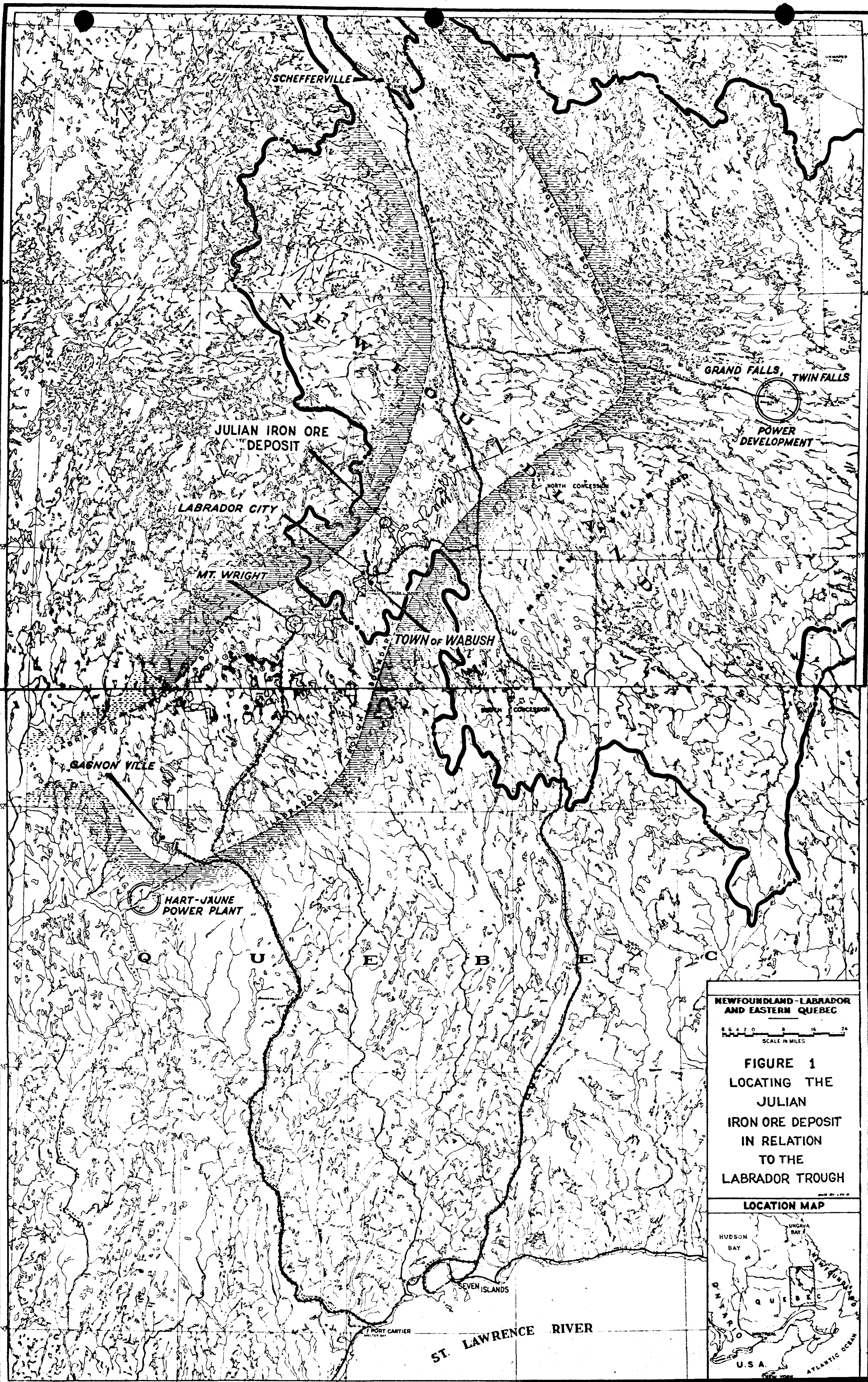


FIGURE 1
LOCATING THE
JULIAN
IRON ORE DEPOSIT
IN RELATION
TO THE
LABRADOR TROUGH

elevation of Wabush and Julienne Lakes is about 1730 feet and the Wapusakatoo Mountains, composed of quartzite ridges, rise to over 2800 feet just west of Wabush Lake.

Well developed glacial striae, eskers and boulder trains indicate that the glaciers advanced from the northwest.

A blanket of bouldery till of variable thickness covers most of the area and outcrop exposures occur predominantly on the hills and in some stream beds. There are two and possibly three separate elevated wave-cut terraces on the hills lying to the east of Wabush Lake.

History of Exploration and Development

The first geologist to recognize ferruginous rocks in the vast Labrador region was Dr. A.P. Low of the Geological Survey of Canada. He reported (1895) unmetamorphosed ferruginous rocks in what is now known as the Knob Lake-Schefferville District of the Labrador Trough.

The metamorphosed iron formation in the Wabush Lake region of southwestern Labrador was discovered in 1914 when a gold prospector was active in the area. The first major geologic report concerning this region was that of Gill, Bannerman, and Tolman (1937).

Exploration crews were in the Knob Lake area in the late 1920's and in the Wabush region by 1949 (Knowles 1967). Interest developed in the Wabush region in the early 1950's due to the presence of billions of tons of easily beneficiated, coarse grained quartz-specularite ore in the Wabush Lake Iron Formation.

Since the early 1950's, intensive geologic mapping, diamond drilling, geophysical and metallurgical testing programs have been conducted throughout the district including the adjoining areas of Quebec, by mining companies, as well as federal and provincial survey agencies. Several students have presented theses on various aspects of the iron formation so that there is presently considerable literature available encompassing economic and general geologic aspects of the rocks within the entire region.

Geologic Setting

The Labrador Trough is a belt of Proterozoic sedimentary, volcanic and intrusive rocks up to 60 miles in width exhibiting evidence of geosynclinal development and lying unconformally upon Archean basement gneisses and granites (see Figure 1). The rock units in the western portion of the belt represent stable shelf, miogeosynclinal sediments. Those to the east represent interfingered miogeosynclinal sediments and eugeosynclinal volcanics. This belt extends approximately 700 miles from the west side of Ungava Bay through the Knob Lake and Wabush Lake regions to the Matonipi Lake area in northeast Quebec. The sequence probably attains a thickness of up to 20,000 feet, Harrison (1952).

The widespread occurrence of sedimentary iron formation exhibiting consistant mineralogic,stratigraphic and structural relationships (described in general by Gross, 1960) has provided a key to the interpretation of the stratigraphic sequence of the entire trough.

This thesis considers an ore deposit in the southwestern portion of the Labrador Trough, therefore, the central (Knob Lake) and northern (Ungava) sections will be considered only briefly. The reader, however, should bear in mind that the sedimentary history of this section is reasonably representative of the entire Labrador Geosyncline. The feature which distinguishes the rocks in the Wabush Lake area from those in the Knob Lake region is that the Wabush Lake area rocks were metamorphosed during the orogenic events which resulted in the Grenville Province. These metamorphosed rocks, however, may be stratigraphically correlated with the unmetamorphosed rocks in the central portion of the trough, and a stratigraphic correlation table (table No. 1) is included for reference purposes.

TABLE I

STRATIGRAPHIC CORRELATION CHART CENTRAL AND SOUTHERN LABRADOR TROUGH

Kaniopiskau Sub group

Central Labrador Trough Churchill Province	Southern Labrador Trough Wabush Lake Area - Grenville Province
Diabasic Gabbro, anorthositic gabbro, Gabbro Lake area	Shabogamo Intrusions, diabasic gabbro, anorthositic gabbro amphibolite
Sims Formation (local) quartzite, grit conglomerate	Not present
----------Unconformity----------	----------
Montagnis Group Retty Formation, peridotite, pyroxenite sill	Not known to be present
Wakuach Formation, gabbro, diorite, meta gabbro	
Doublet Group Willbob Formation, basalt, meta basalt, minor sediments	
Thompson Lake Formation, quartzite, graywacke, shale intercalated basalt	
Murdoch Formation, Agglomerate, breccia, tuff, basalt minor sediments	
Knob Lake Group Menihek Formation, carbonaceous shale, slate, quartzite, graywacke, basic volcanics, minor chert, dolomite	Nault Formation, graphitic arenites, argillites, phyllites, kyanite schist, local granitic gneiss
Purdy Formation (local) dolomite	Not known to be present
Sokoman Formation, iron formation, cherty oxide, silicate and carbonate facies	Wabush Formation, meta iron formation, quartz-iron oxide, iron silicate and carbonate facies
Ruth Formation, ferruginous slate, shale	Huguette Formation, muscovite-biotite schist.
Wishart Formation, quartzite, arkose, minor chert graywacke and slate	Wapussakatoo Formation, massive quartzite, local grit
Flemming Formation, chert breccia, minor shale	Not known to be present
Denault Formation, dolomite, limestone and cherty facies	Duly Formation, quartzose dolomite marble
Attikamagen Formation, shales, slates, phyllites, argillites, intercalated basic flows	Katsao Formation, garnetiferous biotite gneiss, granulite
Seward Formation (local) grit, arkose, conglomerate quartzite, graywacke and acidic flows	Not known to be present
----------Unconformity----------	----------
Ashuanipi Complex (Superior Province) paragneiss, granitized gneiss, hybrid gneiss	Ashuanipi Complex (Superior Province) Garnetiferous, granitoid and pyroxene gneiss altered in Grenville Province

(After Knowles 1967)

Wabush Lake is situated within a few miles of the metamorphic discontinuity marking the northwest side of the Grenville metamorphic province, commonly referred to as the Grenville front. The Grenville front and the northwest edge of the Labrador Trough formations are generally coincident for approximately 30 miles to the north northeast of Wabush Lake.

Archean, Superior province charnokitic gneisses and granites are present immediately northwest of the Grenville front about 12 miles northwest of the Julian deposit.

In the central trough region, rocks similar to the charnockitic gneisses and granites are overlain by essentially unmetamorphosed Labrador Trough formations.

The oldest trough formation rocks in the geosynclinal sequence in the Wabush Lake area are biotite-muscovite gneisses, schists and migmatites of the Katsao Formation.

The Duley Marble (up to 1000 feet thick) and the Wapussakatoo Quartzite (up to 500 feet thick) overlie the Katsao Formation and may be partially contemperaneous. Either or both may be in contact with the overlying Huguette Formation which consists of a 50 to 100 foot thick sequence of muscovite-biotite-sericite schist (Gastil, Knowles, Blais and Bergeron 1960).

The Wabush Lake Iron Formation forms a continuous stratigraphic unit overlying, perhaps unconformably, the marble-and/or quartzite and the micaceous rocks. Because it is the most widespread and readily identifiable formation in the Wabush Lake Region, it has been utilized as a reference for stratigraphic and structural interpretations. It consists predominantly of quartz-iron oxide facies and quartz-iron silicate-carbonate facies.

The uppermost unit of the trough sequence in the Wabush Lake Region is the Nault Formation which contains graphitic arenites, argillites, phyllites, kyanite schists and local granitic gneisses.

The geographic distribution and structural relationship suggest that the stratigraphic units in the Wabush Lake Iron Formation are not time stratigraphic units, but that local mineralogic variations within the formation are best explained by use of the facies concept.

The stratigraphic distribution of sediment types indicates that the carbonate-silicate facies occurs primarily in the lower Wabush Lake Iron Formation whereas the oxide facies is found in the upper iron formation.

The iron oxide facies is not mineralogically homogeneous throughout the Wabush Lake area. Most deposits contain quartz, hematite and up to 30% magnetite, but the

Julian deposit contains quartz and hematite and less than 3% magnetite.

Early workers, including Knowles, (1955) and Knowles and Gastil (1958) have utilized the iron depositional facies concept of James (1954) and White (1954). The application of this concept is somewhat flexible, however, in order to comprehend the complexity of the iron formation in this particular area (Figure 2).

All of the sediments were probably deposited along the eastern shore of an older land mass, and the iron bearing precipitates were deposited in the same basin as the quartzose and carbonate sediments. Oxidizing conditions were probably predominant in the near shore disturbed water, while the deeper more tranquil water areas were characterized by reducing conditions, (Knowles and Gastil, 1958). The availability of iron and silica in both the disturbed and tranquil areas may have been nearly equal, but the oxygen availability was probably much greater in the near shore disturbed water areas resulting in the deposition of oxides of iron. Calcium, magnesium and carbon dioxide, on the other hand, were probably available in sufficient concentrations to unite with the iron in solution and to be precipitated as iron bearing carbonates. Thus, within one basin, two relatively stable iron compounds may have been deposited

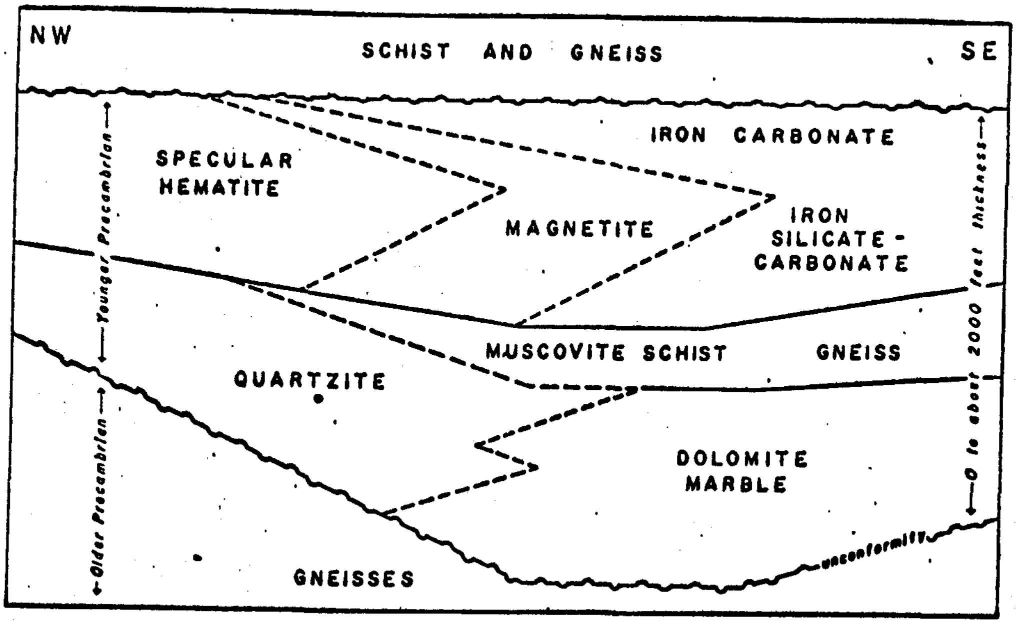


FIGURE 2

DIAGRAMMATIC SECTION ACROSS WABUSH LAKE AREA SHOWING THE DISTRIBUTION OF SEDIMENTARY FACIES IN THE IRON FORMATION

After Gastil and Knowles

(1960)

contemporaneously but under differing environmental conditions, possibly controlled by the configuration of the basin.

The ideal oxide-silicate-carbonate near shore to off shore sequence in the Wabush area is represented by the following rock types: (1) ferric oxide (cherty hematite, limonite), (2) ferric-ferrous oxide (cherty hematite-magnetite), (3) ferrous oxide (cherty magnetite), (4) oxide-silicate (magnetite-iron silicates), (5) silicate (iron silicates and carbonates), and (6) carbonate (cherty ferrugenous carbonate).

Knowles and Gastil (1958) state that with the regression of the sea, the depositional environments migrated to the southeast, such that the shallow water oxide facies was deposited above previously deposited silicate facies, and that the silicate facies was in turn deposited on earlier carbonate facies, etc. Transgressive and regressive cycles perhaps occurred repeatedly but regressive conditions were dominant throughout the period of deposition.

Regional Structure

Early workers in the Wabush Lake region were confronted with confusing structural and stratigraphic relationships. In 1957, however, Weiss recognized two fold systems in which the fold axes intersect at high angles. The axes of one fold system trend to the northeast, and the axes of the other system trend to the northwest. The time and geometric relationships between the two fold systems were recognized in 1958 and 1959 and the time relationship was later revised by Knowles (1967).

Knowles (1967) has recognized a large regional fold system trending northeasterly through the Wabush region and suggests that trough formations within this system commonly exhibit arcurate to linear patterns that are related to a fairly uniform northwest-trending superposed fold system which has reoriented the earlier system in several localities. He describes a small fold observed in outcrop about 10 miles southwest of the Julian deposit during his regional examination which conclusively demonstrates that the northwest trending folds are younger, and have been superposed on the northeasterly trending system and probably are an expression of the diastrophism of the Grenville province. He interprets the older system as being structurally equivalent to the post trough Hudsononian fold system in the Central Labrador Trough.

The Grenville front is an approximately four-mile wide zone which parallels and is coincident with the northwest edge of the Labrador Trough in the Wabush Lake region. The older northeast trending fold system in the trough formations essentially parallels the Grenville Front zone, whereas the superposed northwesterly trending fold system is basically continuous across the front zone. The deformational effects of superposed folding increase to the southeast. This is shown by cataclastic features in the Superior Province gneisses, by openly folded trough formations within the Front zone and by tightly folded passive folds with variable amplitudes in the Grenville Province southeast of the front zone (Knowles 1967).

Metamorphism

The rocks in the Labrador Trough north of the Grenville front are essentially unmetamorphosed. Within the Grenville front zone in the Wabush-Mt. Wright (Quebec) region however, all workers who have studied the trough rocks have noted assemblages stable in the quartz-albite-muscovite-chlorite-subfacies of the greenschist facies within the front zone proper, and assemblages of the almandine-amphibolite facies to the south of the front. Fahrig (1960) located the approximate position of the biotite isograd along the Grenville front and described the mineralogic composition of the rocks on either side of the front zone. The almandine-amphibolite facies is reported to be fairly uniform within the Grenville province from Mt. Wright, through to Wabush, Julienne and Shabogamo Lakes, but

(Knowles 1967) suggests that the metamorphic rank decreases non-uniformly towards the biotite isograd. This is based on the occurrence of partially recrystallized quartzite, chloritic schists, phyllitic rocks and areas of iron formation containing distinct granular quartz and fine grained hematite (indicative of partial recrystallization) between the front zone and the area of amphibolite rank metamorphism. The metamorphic rank is somewhat irregular north and west of Wabush-Julienne-Shabogamo Lakes, whereas it is fairly uniform amphibolite rank to the southeast. Jackson, (1962), observed remnants of cherty bands in some outcrops, and oolites in thin sections of metamorphosed iron formation collected in the Neal Lake area west of Wabush Lake. These features show the originally fine grained cherty iron oxide nature of the iron formation.

Post Metamorphic Alteration

Observation of megascopic features such as the remains of leached iron silicate minerals, and the presence of limonite-goethite and soft red hematite in the Julian and Wabush deposits suggests that these deposits have suffered post metamorphic oxidation and leaching. The current study investigates the nature of the alteration by microscopic examination of the resulting mineralogy and the associated changes in magnetic properties.

CHAPTER II

The Julian Deposit

General Description

The Julian deposit covers an area of approximately 300 acres. It is over 5000 feet long and varies in width from 2000 to 3300 feet.

The most prominent topographic feature on the Julian peninsula is a small hill (Figure 3) rising 220 feet above Wabush Lake. This hill contains the Wapussakatoo quartzite, a sericitic muscovite schist, probably the Huguette Formation and the Wabush Lake Iron Formation. There are excellent natural outcrop exposures along an elevated glacial beach produced by the wave action of Glacial Lake Wabush on the west, north, and east sides of the hill. A 2300 foot long buldozed exposure across the strike and over 300 outcrops on the hill have provided the writer with representative hand samples from over 400 locations. The starting point of the Julian grid system 10,000N/10,000E is situated approximately in the center of the deposit and the north south base line has an azimuth of N0° 00' magnetic. With the exception of the "trench" coordinate numbers which pertain to the bulldozed area, all sample locations

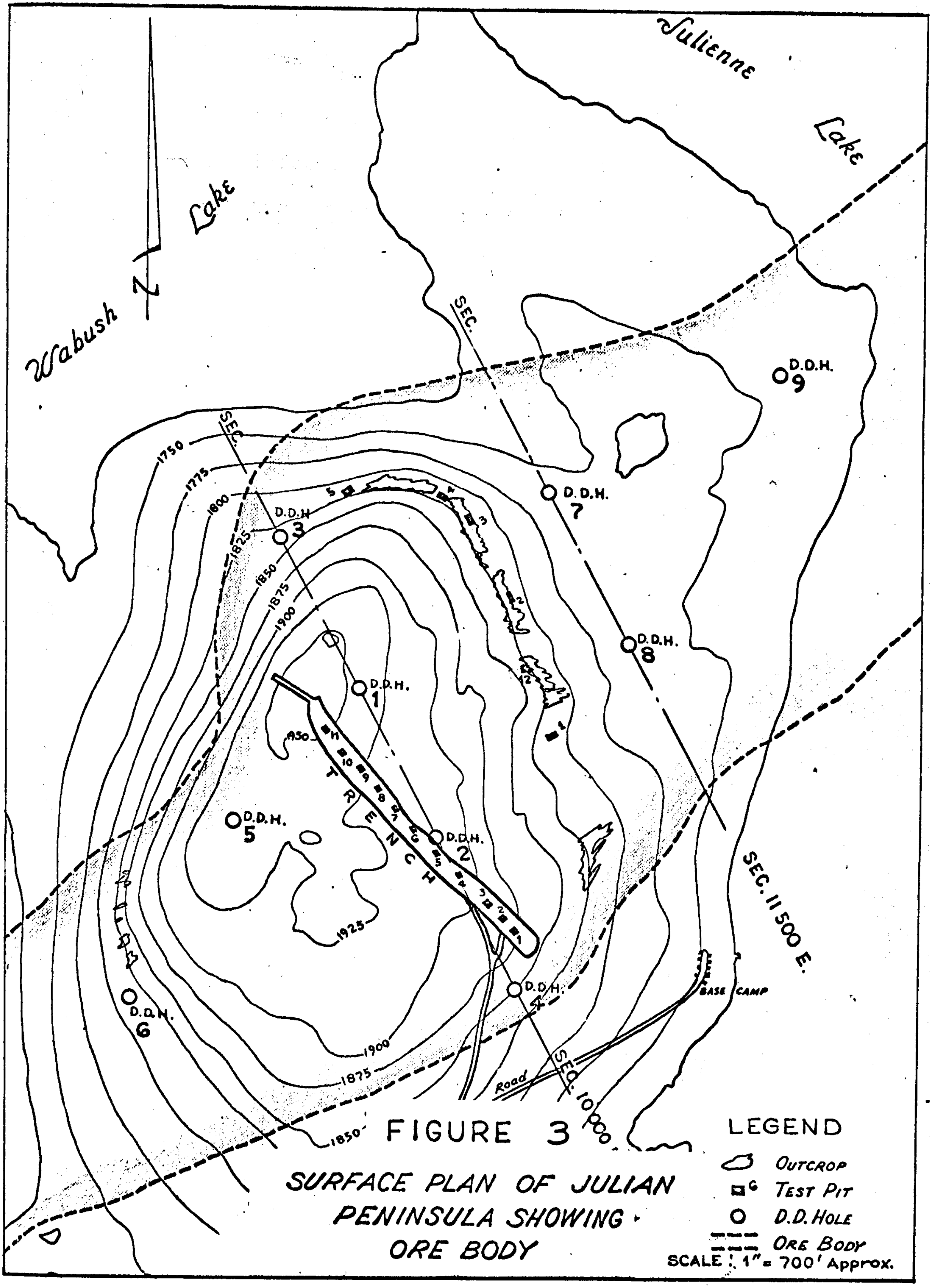


FIGURE 3

SURFACE PLAN OF JULIAN PENINSULA SHOWING ORE BODY refer to the Julian grid system.

Present information is based upon mapping, outcrop sampling, magnetic surveying and diamond drilling programs conducted during field operations from 1956-1963. The writer has participated in all field programs since 1956 with the exception of the diamond drilling in 1957-58.

The principal minerals of the deposit are quartz and hematite, as specular or granular forms, earthy red hematite, goethite, limonite, very minor amounts of magnetite and other minerals of an accessory nature. Eight different varieties composed of varying combinations of the above minerals have been recognized in the Julian deposit by Canadian Javelin personnel (Figure 4, Plate 1).

Except for a thin band (which is believed to represent altered carbonate-silicate facies) at the base of the Julian deposit, the entire ore body consists of quartz-iron oxide facies iron formation. The rock, however, is neither physically nor mineralogically homogeneous; some bands are thinly bedded while others are massive across thicknesses measurable in tens of feet, other bands, moreover, are irregular on all scales. Mineralogic variations are equally diverse; some bands consist of quartz and specularite, while others consist of quartz and granular hematite or mixtures of quartz, specularite, and granular hematite.

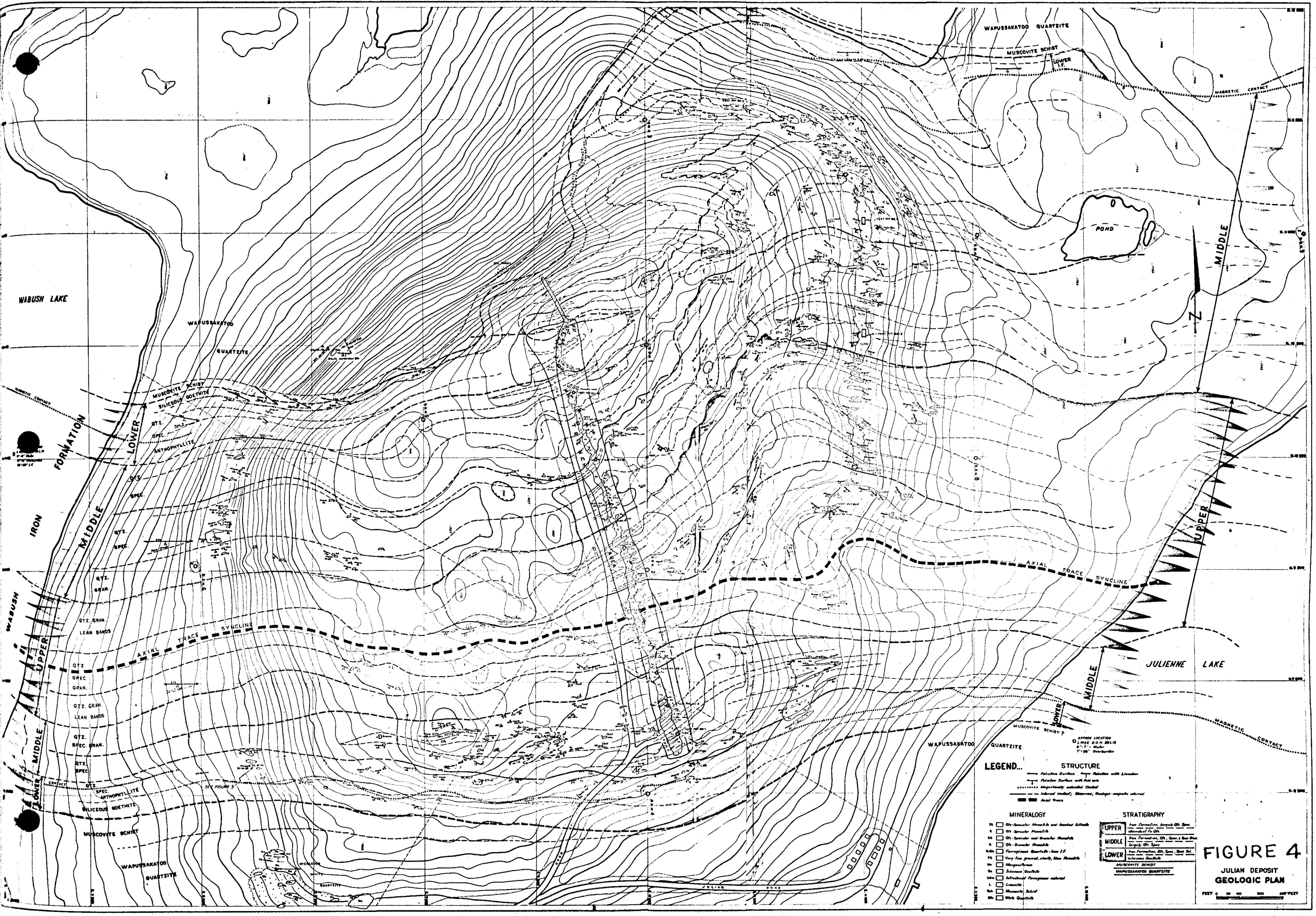


FIGURE 4

JULIAN DEPOSIT
GEOLOGIC PLAN

The relicts of a silicate mineral, manganese oxides or hydroxides, and variable amounts of secondary iron oxides are also present.

The mineralogic distribution appears to be largely stratigraphically controlled because mineralogic changes are very pronounced across the strike whereas individual bands are fairly uniform along strike. These features may be observed in deposits of quartz-specularite-magnetite in this region, and indicate that existing mineralogic variations strongly reflect depositional and stratigraphic mineralogic-compositional changes in spite of intense regional metamorphism.

Mineralogy

Identification of the ore types as presented on the accompanying geologic maps (Figure 4 and Plate 1) has been made on the basis of physical appearance and megascopic (including hand lens) mineral identification. No microscopic studies of Julian ore have been undertaken prior to the present work.

The following definitions and descriptions are presented so that the reader may visualize the important minerals and mineralogic assemblages presented in the text and on the geologic maps.

Iron Mineral Definitions

Specularite - Coarse grained, 1.0 - 2.5 millimeters, crystalline, euhedral tabular hematite which has a rifle barrel blue color, a bright metallic lustre and red streak.

Granular Hematite - Medium grained, 1.0 - 2.0 millimeter, non-tabular dull, reddish brown, gray to black hematite with a red streak, and which may occur as recognizable individual euhedral or irregularly shaped grains or in massive forms.

Earthy Hematite - Very fine grained, soft, red hematite without discernable grain forms. This material occurs in fracture fillings and as a stain on quartz grains associated with the other iron oxides and in massive zones measurable in tens of feet in width.

Limonite - Soft, earthy, yellow-brown hydrous iron oxide, commonly occurs with goethite and as a stain or fracture filling material.

Goethite - Fine grained, hard, brown-black hydrous iron oxide occuring primarily as a fracture filling material.

Ore Types

The combination of quartz and one or more of the iron oxide minerals, plus other observable physical features as hardness, friability, crystal form, massiveness, foliation and colour have led to the classification of eight mineralogic varieties of iron formation.

Quartz-Specularite - This mineralogic variety is essentially bi-mineralic and is composed of variable proportions of quartz and specular hematite. The material is occasionally extremely friable. It is easily recognized because of the reflective nature of the tabular basal planes of specularite which are in a schistose arrangement. It is frequently bedded in quartz rich and specularite rich bands varying from less than 1/8 inch to over one inch in thickness.

Quartz-granular hematite: This material commonly consists of a mixture of quartz and dull, individual, blue-gray-black to reddish-brown grains of granular hematite, but it may also consist of masses of granular hematite without discernable grain boundaries surrounding isolated quartz grains. Considerable limonite-goethite or soft red hematite may also be associated with this variety. The ore may be dense or friable, and the grains may or may not exhibit a preferred orientation or compositional layering.

Quartz-specularite-granular hematite: all occurrences containing specularite and visually estimated granular hematite greater than 20% have been placed in this classification. Samples may exhibit well developed foliation or be structureless with randomly oriented grains. The granular hematite may be either in massive zones or occur as discrete grains. The specularite, however, generally occurs as definitely euhedral grains. There may also be a considerable latitude in the degree of induration, from hard dense types to those which are very friable. Soft red hematite and brown-black goethite are also frequently associated with this variety.

Manganiferous Ore: this variety is easily recognized due to its black color and sooty nature. The manganese oxide (or hydroxide) is frequently in a powdered form, filling the intergranular spaces between quartz and iron mineral grains. A coating of manganese oxide has deprived all grains of any lustre.

Quartz-specularite-relict silicate: this is one of the most easily recognized of the mineralogic types. It is highly schistose, quite friable and ordinarily has a light orange to cream color due to clusters of casts of a needle like silicate mineral. The combined preferred orientations of the quartz and specularite grains as well as the silicate casts form a rock with well developed lineation and foliation. There does not appear to be any granular hematite associated with this mineralogic variety.

Very fine-grained hematite: this material exists only in a few thin sheets or lenses, never more than a few tens of feet thick. It is massive, very hard, brittle, and commonly aphanitic. The iron could be in the form of either very fine-grained specularite, granular hematite or both, and the rock often has the appearance of highly ferruginous chert.

Ferruginous quartzite: as the name implies, this material is easily recognized by high quartz, low iron-mineral content (generally less than 20%). It is frequently stained pink to rusty red or brown by red hematite and often carries veinlets of goethite or limonite. The coarse grained iron mineral is usually granular hematite although specularite is observed occasionally.

Siliceous goethite: this is somewhat nondescript yellowish-brown colored rock containing variable proportions of fine grained crystalline and cherty quartz and goethite-limonite. It occurs most commonly in the basal member of the iron formation and probably represents the altered silicate-carbonate facies.

No polished sections were made of this material due to the very poor quality and limited number of samples.

Stratigraphy

The stratigraphy of the Julian deposit, as presented on the accompanying geologic maps (Plate 1 and Figure 4), is based on the megascopic stratigraphic and mineralogic classification of outcrops and diamond drill core, aided by the interpretation of ground magnetic data. Well developed compositional banding is exposed in a few outcrops and is best exhibited in the bulldozed exposure where individual bands of a particular mineralogic variety may vary from 10 to over 100 feet in thickness. The average thickness of most of these bands, however, is from 10 to 25 feet.

Three formations, the Wapussakatoo quartzite, the Huguette schist and the Wabush Lake Iron Formation are present in the Julian peninsula.

The Wapussakatoo Quartzite, a major stratigraphic unit of the trough sequence in the Wabush Lake region, is present on both sides of the Wabush Lake Iron Formation in the Julian deposit. It is a white, coarse grained, recrystallized orthoquartzite with scattered, thin seams containing muscovite and sericite which are more abundant near the contact with the overlying Huguette Formation.

The Huguette Formation is present as a bed of sericite-muscovite schist, not more than thirty to fifty feet thick.

Canadian Javelin personnel have subdivided the Wabush Lake Iron Formation into three major units, i.e., the upper, middle and lower members.

The writer wishes to emphasize that the presentation of the three members of the Wabush Lake Iron Formation on the accompanying maps is somewhat arbitrary because it is based on the outcrop distribution of mineralogic types across the strike of the deposit and the generalized interpretation of ground magnetic data. Distinct boundaries are lacking and it is very likely that other students of this deposit might easily develop alternate stratigraphic arrangements.

The lower Iron Formation consists of two submembers, the lower, principally goethite and minor amounts of granular hematite, and the upper, which contains the quartz-specularite and quartz-specularite relict silicate mineralogic varieties.

The middle Iron Formation consists of all of the stratigraphic units lying above the quartz-specularite-relict silicate unit up to and including lean ferruginous quartzite. Mineralogic varieties are (1) quartz-specularite,

(2) quartz-specularite-granular hematite, (3) thin zones of extremely hard, very fine-grained hematite, (4) bands of black manganiferous hematite, and (5) quartz-specularite. The last is the most common mineralogic variety in the middle member.

The upper member of the Wabush Lake Iron Formation is characterized by several bands of quartz-granular hematite and quartz-specularite-granular hematite. The stratigraphic top of the Wabush Lake Iron Formation is not exposed on the deposit.

Structure

The presence of the older Wapussakatoo quartzite on both sides and below (evidenced by diamond drilling) the deposit, and the trend of the stratigraphic units in the Iron Formation indicates that the major structure is a northeasterly trending syncline. The northern limb dips 25° to the south or southeast. Diamond drilling, magnetic information and other structural evidence indicate that the south limb stands nearly vertical near the surface. (Figures 5 & 6). The syncline is asymmetrical and overturned to the northwest and its axial surface dips south to southeast. Diamond drilling and magnetic

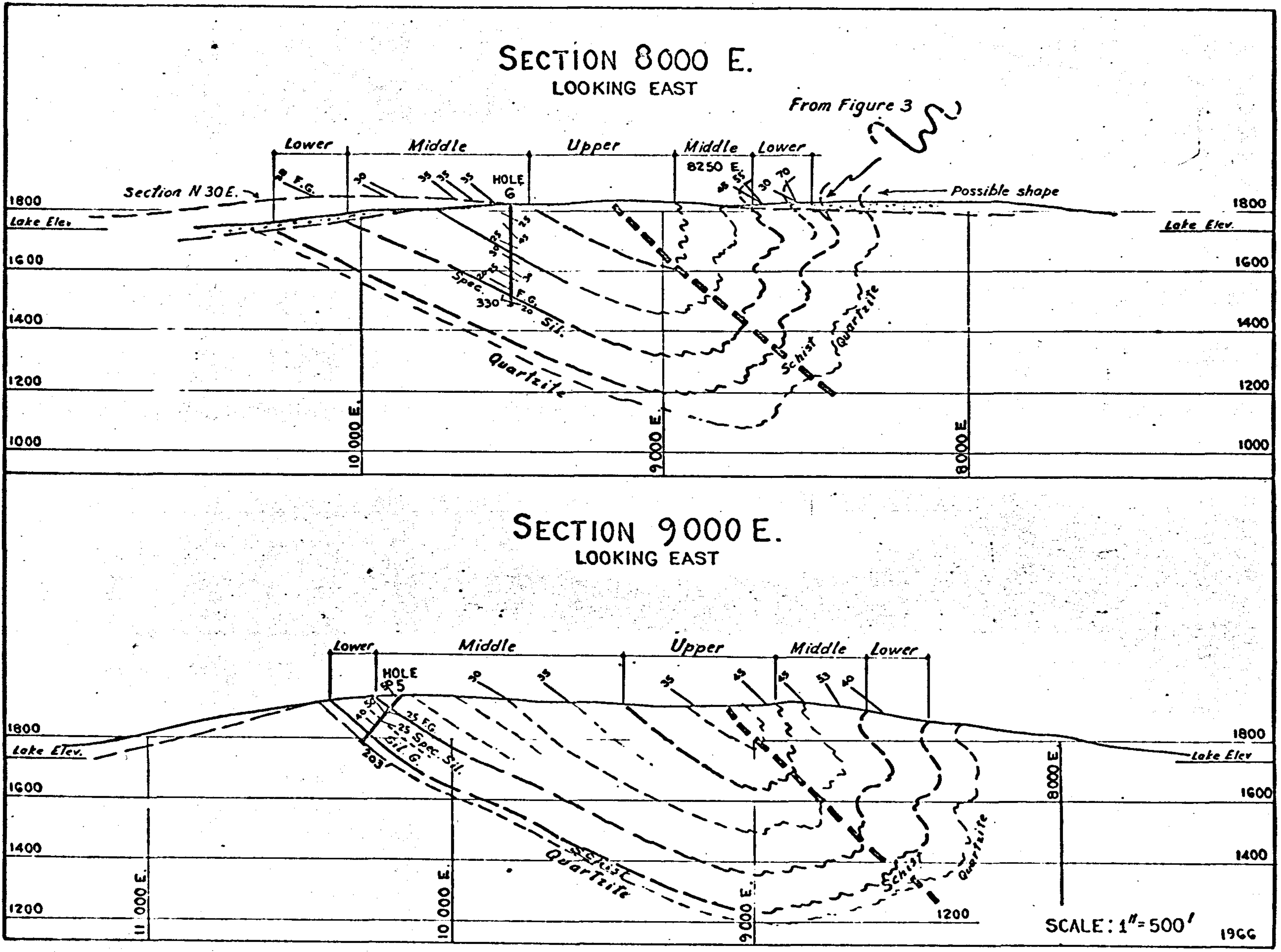


FIGURE 5

JULIAN DEPOSIT - SECTIONS 8000 E. AND 9000 E.

After Knowles (1967)

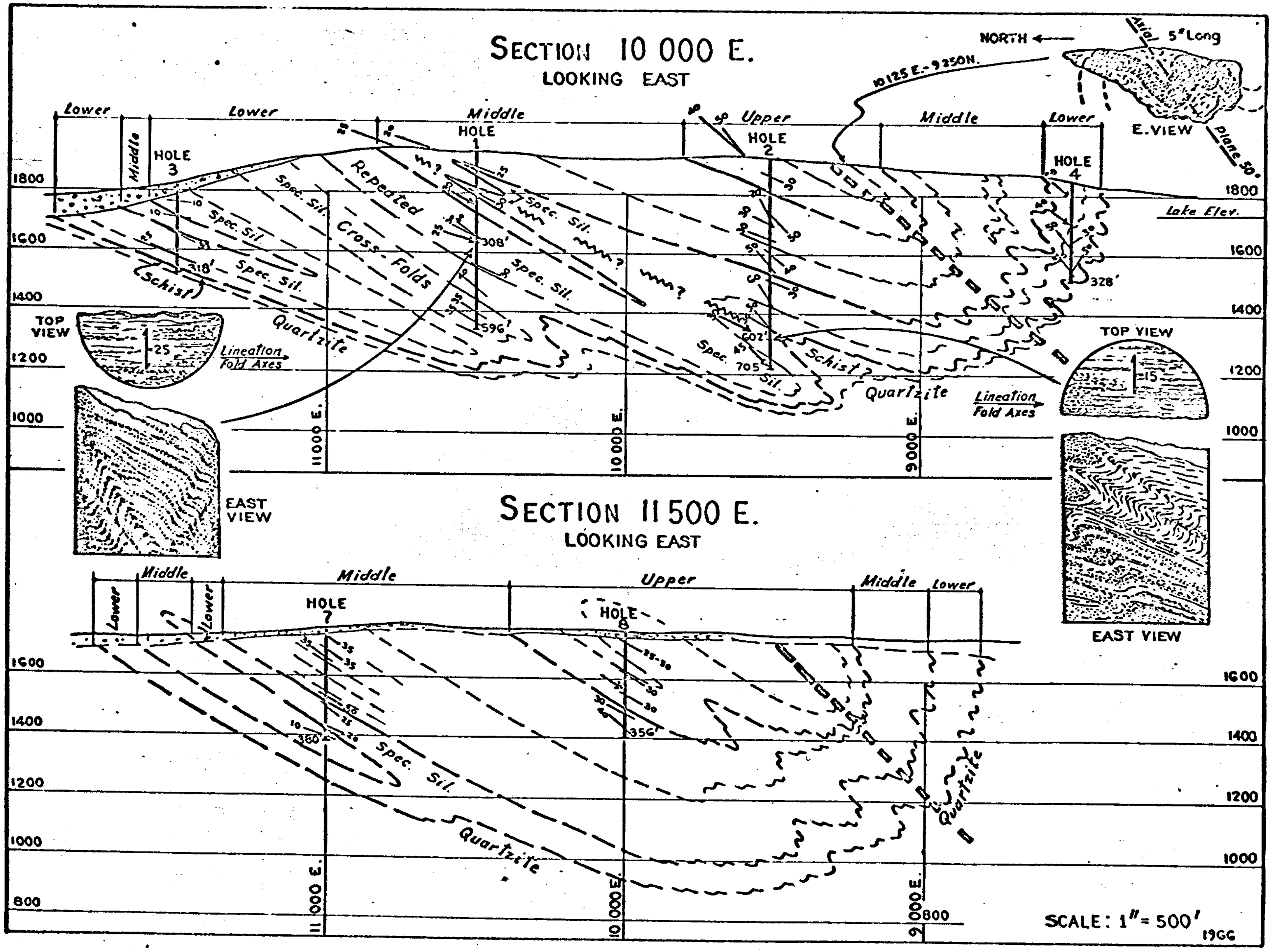


FIGURE 6

JULIAN DEPOSIT - SECTIONS 10,000 E AND 11,500 E.

After Knowles (1967)

evidence indicate that the iron formation extends over 5000 feet to the east and west of the peninsula.

The interpretation of arcuate stratigraphic patterns in outcrops and lineations and minor folds in both outcrops and diamond drill core, indicates that cross folding has modified the simple synclinal form and produced the culmination north and east of 10,000N/9500E.

Knowles (1967) determined that the superposed folds are better developed in the northern limb and that superposed folding has not seriously affected the southern limb. The superposed folding has, however, produced a mappable south-plunging antiform and a gently plunging synform within the north limb.

Knowles (1967) suggests the following deformational sequence:

(1) The development of the syncline with presently subhorizontal axes trending east and an axial plane dipping to the south.

(2) The development of the superposed folds with non planar southerly trending axial surfaces, and variable plunges which are dependant upon the inclination of the foliation surfaces upon which they were formed.

CHAPTER III

Mineralogic Investigations

The one hundred samples to be studied in polished section were selected from 419 samples of individual outcrops as per table II.

TABLE II

SAMPLE VARIETY AND QUANTITY

No. of Samples	Mineralogic Variety	%	No. Selected
152	Quartz-Specularite	36.1	35
59	Quartz Granular Hematite	14	13
103	Quartz-Spec.-Granular Hem.	24.6	25
8	Quartz-Spec. Manganese Oxide	2	4
18	Quartz-Spec.-Relict Silicate	4.3	4
38	Very Fine Grained Hematite	9	9
41	Ferrugenous Quartzite	10	10
419		100%	100

The number of samples selected for each type was adhered to as much as possible, but some substitutions were made in the course of the study due to loss, contamination, or extremely small size of a particular sample.

The procedures utilized to select specific samples, and their specimen numbers are presented in Appendix A, and the locations of the selected samples are indicated on the geologic map (Plate I).

Sample Preparation

Selected specimens were broken to a .5 to 1.0 inch cube cut at right angles to the mineral foliation, mounted in Bio-Plastic, labelled and polished on a grinding belt and lapidary wheel. Extremely friable specimens were impregnated with Bio Plastic prior to mounting. Detailed information concerning mounting and polishing procedures is presented in Appendix B.

Polished Section Study

The polished sections were examined with Nikon Model Unitron MM6 metallographic microscope under direct and oblique (from an outside source) reflected light. (A blue filter was used on the direct light source.)

Most examinations were made at 50 or 100 power magnification and 400 power magnification was used occasionally. Grain size determinations were made with a Nikon adjustable micrometer. An average of 500 point counts was made for each specimen using a Swift automatic advancing point counting device which moved the specimen .3 millimeters per advance. The point counting device was mounted on a petrographic microscope, adapted to use direct reflected light, occasionally in conjunction with oblique reflected light.

All specimens were tested with hydrogen peroxide to determine the presence of manganese oxide or hydroxide. The strong, moderate or weak bubbling reaction to the hydrogen peroxide, and the portion of the sample exhibiting the reaction, i.e., intergrain areas, grain surfaces, vugs, etc. was entered on the specimen data sheet (Appendix C).

Magnetic determinations were also made on each sample. Selected grains of the ferruginous material were scratched with a magnetized dental probe. The degree to which the loosened particles were attracted to the magnetized probe, i.e., strongly, moderately, or weakly was entered on the data sheet.

It was not possible to optically determine the crystallographic axes of individual grains because all specimens were opaque and examined in reflected light. Examinations were made, however, to determine the mineralogy, grain sizes, shapes and orientations, intergrain boundary relationships, genetic evidence, relict structures, strain or fracture features, relative abundance of different minerals, and any unusual features, in a specimen. The degree to which each of these items could be determined differed from one sample to another.

The grain count mineral percentage determinations provide estimates of the volumetric proportions from a two dimensional surface, and of course are not gravimetric determinations.

Iron Oxide Mineral Descriptions

Descriptions of the iron oxide minerals, as they appear microscopically, are presented below.

Specularite: Tabular, bladed, generally euhedral with distinct intergranular boundaries and sharp corners at 60° and grain widths usually at least twice the thickness. Bright silvery blue to black in color, usually highly reflective, red streak.

Granular Hematite: (Megascopic Term) Commonly equi-dimensional hematite grains, frequently square possibly representing a section cut perpendicular to a crystallographic axis of a former magnetite octahedron (Martite) or it may occur without recognizable crystalline or grain form, composed of innumerable crystals, too small to be distin-

	guished individually (amorphous hematite)-generally dull gray to black in color - red streak.
Soft Red Hematite:	Non crystalline, red hematite, very soft - occurs as a coating and micro fracture filling material.
Magnetite:	Generally euhedral triangular grains, representing a portion of an octahedral face, silvery black in color, black, magnetic powder, black streak.
Limonite-Goethite:	Durable to friable, dull to moderately reflective, brown to black in color - yellow-brown streak. Limonite occurs as a yellow-brown earthy coating and goethite occurs as a more crystalline fracture filling material.

Observations

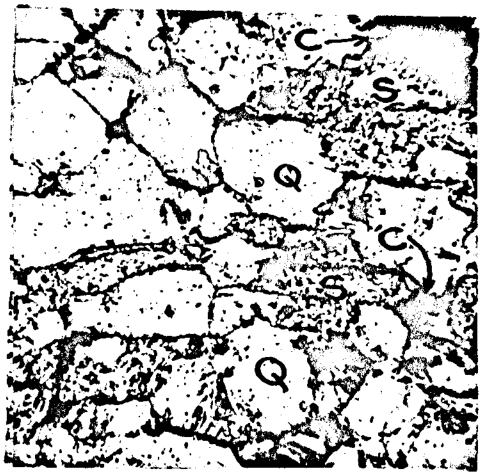
The mineralogy and physical features observed through microscopic examination of the polished sections, and their quantitative aspects per mineralogic type are presented below:

The number of specimens per mineralogic variety as discussed below does not, in some instances, agree with that presented on page 34. This is due to reclassification of the specimens following their microscopic examinations. A recapitulation of the reclassification of mineralogic varieties is presented following the descriptive material.

Quartz-specularite variety: Although the fabric and morphology of this variety is fairly uniform (Figure 7), the specularite content varies from 20% to 75% by volume. This is probably a function of variations in compositional layer thickness on a microscopic scale. All of the specimens exhibit a very well developed parallel orientation of what would (optically) be the 'a' axes of both quartz and specularite grains. This is due to commonly parallel quartz-rich and specularite-rich compositional layers which are coincident with the foliation.

The specularite in twelve of the twenty specimens responded weakly to moderately to the magnetized probe, and one exhibited a strong response. The specularite in the remaining seven specimens did not react. The grain boundary areas of eight of the specimens reacted weakly to moderately to hydrogen peroxide.

The quartz grains average .2 - .4 millimeters in size and are either euhedral angular or anhedral angular, and in 90% of the samples the quartz-specularite boundaries are clean and not intergrown. The boundaries between



Q - Quartz
S - Specularite
C - Cavities lined with limonite

FIGURE 7

PHOTOMICROGRAPH OF SPECIMEN #14 QUART-SPECULARITE FROM 11,150N-10,975E. MAG. 40x (APPROX) adjacent specularite grains which average .2-.5 millimeters in size, are not always completely parallel, however, because in two samples the blades of specularite were found to intersect each other at angles of 5° - 10° (Appendix C,p147).

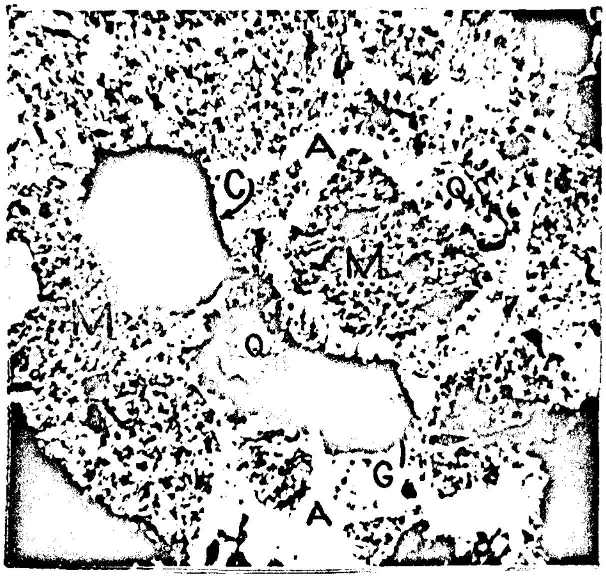
Trace amounts of amorphous hematite were observed as fracture fillings in quartz and specularite grains, and in a few cases as an intergranular material.

The only definitely identifiable magnetite in the 100 polished sections examined was found in one specimen of this variety. This was #6 (9745N/8660E)where six or eight distinct, isolated, black, euhedral, triangular grains (which produced a black magnetic powder when crushed) were observed in the polished section. These grains were observed in both quartz- and specularite-rich bands, during the preliminary examination, but only three were encountered in the 500 point count.

Approximately ten per cent of the quartz in specimen No. 72 has very indistinct boundaries, and is similar in appearance to chert. This feature suggests secondary recrystallization of quartz. The relict grain boundaries in the cherty areas indicate that the quartz grains averaged .2 - .4 millimeters in size. The volumetric specularite content of this specimen is 25.4 per cent.

Quartz-granular hematite variety: the predominant characteristic of this mineralogic variety is the presence of dull, gray-black granular hematite in every specimen, (Figure 8). Under the microscope it was observed that some of the granular hematite (a megascopic term) exhibits partial or full crystal outlines which vary from triangular to square, with intermediate forms depending on the orientation of the grain in respect to the observed surface. Other grains (more aptly described as areas) of granular hematite, however, do not exhibit distinct crystal forms but are masses of innumerable crystals too small to be individually distinguished. The material with recognizable crystal outlines will herein be called martite, which is hematite, pseudomorphous after magnetite, and the material without crystal form will be called amorphous hematite. Estimates were made of the amount of material present as amorphous hematite with indistinct grain boundaries and the amount present as discernable individual martite grains.

Twenty-five to fifty per cent of the observed surfaces of sixteen of the twenty-four specimens exhibited areas of massive, amorphous hematite with recognizable martite grains and quartz inclusions. The general appearance is that of quartz grains completely engulfed by hematite, suggesting that these zones were formerly martite rich, with



Q - *Quartz*
A - *Amorphous Hematite*
M - *Martite*
G - *Goethite*

FIGURE 8

PHOTOMICROGRAPH OF SPECIMEN #19
QUARTZ - GRANULAR HEMATITE FROM
9,390 N./10,810 E. MAG 40 x (APPROX)

a few isolated quartz grains. Evidence of solution of hematite and redisposition as amorphous hematite is exhibited in twelve of the samples where fractures in quartz and martite grains and inter quartz grain areas have been observed to be filled with amorphous hematite. (see Appendix C p.148).

Another prominent feature of all but four of the specimens is the generally random orientation of individual quartz and martite grains. Trace amounts of specularite were noted in ten specimens, and in seven of these the specularite showed a preferred orientation.

A very striking feature of the amorphous hematite noted in this mineralogic variety is the frequent occurrence of relict crystal outlines. These are often rhombic or equilateral triangular 'ghosts' which are dark gray or black in contrast with the lighter gray amorphous matrix (see Appendix C p.146). They are entirely hematite, however, because they have a red streak. The presence of the relict structures, similar in form to magnetite, in fifteen of the twenty-four samples, strongly suggests that these relict forms are an oxidation product of magnetite and are in fact martite. The very fine-grained amorphous hematite may be the result of the loss of martite grain boundaries through post metamorphic solution and redeposition of amorphous hematite in situ. Perhaps the amorphous hematite was formed directly from magnetite without first becoming martite. In other words, martite may have formed when there was no movement of material (other than the addition of 0^{-}) and amorphous hematite may have formed in a dynamic open system.

The predominant grain size for quartz and individual martite grains was found to be from .2-.5 millimeters for twenty-one of the specimens studied. Three samples exhibit grains smaller than .2 millimeters.

Nine of the samples exhibit varying amounts of quartz grains containing opaque inclusions less than .02 mm in size. These are black and have the crystal form of magnetite grains under 400 power magnification. The inclusions in the quartz grains frequently appear to be in an aligned pattern parallel to the foliation.

The boundaries between quartz and martite grains were found to be interlocking in over 50% of the specimens due to the spatial relationship of quartz and amorphous hematite or randomly oriented martite grains. The majority of the quartz - quartz grain boundaries were found to be non intergrown however, as most of the quartz grains are euhedral, angular and have smooth faces, commonly forming triple junctions.

Sixteen of the samples reacted to hydrogen peroxide indicating the presence of manganese oxide (or hydroxide).

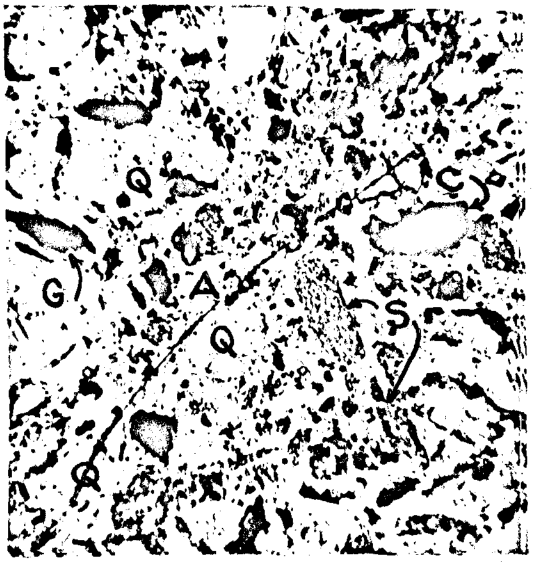
Powdered martite and amorphous hematite were found to be weakly magnetic in all of the samples.

The percentage of hematite (martite and amorphous hematite combined) varies from 25% to over 71%, with the 31%-35%, 41%-45%, and 46%-50% groups each containing four samples.

Quartz-specularite granular hematite: this variety exhibits wide variations in the proportions of specularite-granular hematite (including recognizable martite). The point counts show that the range is from 10% specularite/90% granular to 90% specularite/10% granular. The thirty-three specimens are quite evenly divided in the following specularite/granular proportions: 10/90, 30/70, 40/60, 80/20, and 90/10. The total hematite content of most of the specimens averages about 31-35%.

The average grain size is .2 x .5 millimeters for the specularite, .15 - .4 mm for recognizable martite and .15 - .4 mm for the quartz (Figure 9). Masses of amorphous hematite vary in size from 1.0 millimeter to over 10 millimeters.

Most of these samples exhibited negative to weak reaction to hydrogen peroxide on the metallic surfaces as well as in the intergranular areas, indicating the presence



S - Specularite
Q - Quartz
A - Amorphous hematite
G - Goethite
C - Cavity (Former carbonnate mineral ?)

FIGURE 9

PHOTOMICROGRAPH OF SPECIMEN #70
QUARTZ - SPEC., GRANULAR HEMATITE
FROM 10,200N/8,310E. MAG. 30X (APPROX)

of minor quantities of manganese oxide (or hydroxide). The responses of the hematite particles to the magnetized probe were also weak to moderate, one sample exhibited no visible response, and three exhibited a very strong response. The magnetic responses of both martite and specularite are approximately equal for a given specimen. This suggests that the degree of magnetism is not dependent on the chemical state of hematite.

The martite commonly exists as bands of nearly equidimensional grains but zones of amorphous hematite, comprising up to 35% of the total Fe_2O_3, are present in 65% of the sections studied. The relict crystal structure which may represent former magnetite grains is present in 75% of the samples containing amorphous hematite.

Secondary soft red hematite was observed in 25% of the samples studied, and goethite and limonite are present in the same number, although not always the same specimens. The goethite was observed to occur as discrete grains and the limonite as a brownish-yellow stain on quartz grains.

As might be expected, the samples with a greater percentage of specularite exhibit the greatest degree of preferred orientation. The traces of the basal planes of the specularite grains have a parallel alignment on the observed surface and individual martite grains exhibiting nearly equidimensional form appear to be zoned between quartz and specularite grains.

Iron mineral inclusions (not identifiable as specularite under 400 power magnification) appear in scattered quartz grains in 30% of the samples. The quartz grains containing inclusions are randomly distributed in most cases, although a layering of these grains is suggested in a few samples.

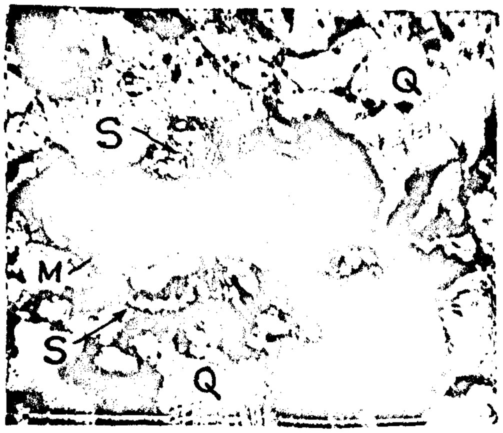
Fractures in quartz, specularite and martite grains in nearly every sample contain amorphous hematite.

Martite grains boundaries are distinct in all samples and a few examples were noted in which distinct martite grains were engulfed in amorphous hematite.

The quartz grains are generally euhedral and angular with noninterlocking boundaries. Most of the samples exhibit noninterlocking or nonintergrown quartz - martite and quartz - specularite boundaries except in those cases in which quartz grains are in contact with amorphous hematite. Specularite grains are predominantly euhedral and tabular although in sample No. 66 the specularite grains appear to be slightly deformed around the quartz grains.

<u>Quartz-specularite manganese oxide</u>: this variety is essentially quartz-specularite and over 10% manganese oxide (or hydroxide) powder. One specimen contains 2% martite and another contains 15% of a hard black anhedral, non magnetic

manganiferous mineral tentatively identified as hausmanite. The soft manganese oxide (hydroxide) minerals fill all intergranular areas, (Figure 10) and have stained the quartz and specularite grains black.



M - *Manganese oxide*
Q - *Quartz*
S - *Specularite*

FIGURE 10
PHOTOMICROGRAPH OF SPECIMEN #2
QUARTZ-SPEC.-MANGANESE OXIDE
FROM 9,080N/10,825E. MAG 40X (APPROX)

All of these samples reacted violently to hydrogen peroxide. The specularite was found to be non magnetic to very weakly magnetic.

The specularite grains are euhedral, tabular and average .2 x .6 millimeters in size and the quartz grains are generally euhedral, angular to subrounded and average .2 - .4 millimeters. The traces of the basal planes of specularite grains are parallel in all specimens.

The specularite content ranges from 26% - 42%, and the manganese oxide content, based on the occurrence of dull black powdery areas in the polished sections, ranges from 13% to 29%.

Two percent martite was observed in sample No. 100 (from 9080N/10750E.)

Quartz-specularite-relict silicate: samples of this material were also found to be quite homogeneous morphologically. The rock is essentially quartz-specularite containing up to 18% in casts or cavities marking the former presence of clusters of needle like crystals less than 2.5 millimeters in length and which had the form of an amphibole. The casts average .15 x .35 millimeters in cross section while the quartz and specularite grains average .2 - .4 millimeters and .2 x .6 millimeters respectively (Figure 11).

The long cross section dimensions of the cavities, specularite grains, and quartz grains were found to be parallel to each other as observed on the polished surfaces cut perpendicular to the foliation of the rock. Intergrain boundaries between quartz, specularite and the casts are generally sharp and parallel to the long axes of the grains.

The quartz and specularite commonly occur in discrete

SC - Silicate cast
Q - Quartz
S - Specularite
C - Cavity lined with limonite

FIGURE II

PHOTOMICROGRAPH OF SPECIMEN # 95
QUARTZ-SPECULARITE RELICT SILICATE
FROM 11,100N/11,215E. MAG. 30X (APPROX)

bands, the same as is in the quartz-specularite variety, but the silicate mineral casts appear to be approximately equally distributed in the quartz and specularite bands.

The specularite in all of the polished sections was observed to be very weakly magnetic when tested with the dental probe. Reactions to hydrogen peroxide were negative to very weak, indicating that these specimens are either free of or contain very minor amounts of manganese oxide.

Sample No. 96 is mineralogically different because it contains only 3.6% specularite, 27% combined amorphous hematite and martite, and 65% quartz. About 16% of the specimen is amorphous hematite with a few relict structures which may represent former magnetite grains, and an occasional engulfed quartz grain. The relict silicate casts comprise 4.4% of the specimen.

An additional anomalous feature of this specimen is the presence of zones of cherty quartz, constituting approximately 60% of the silica present. The relict silicate mineral casts are spatially associated with the martite-amorphous hematite, specularite and euhedral quartz grains rather than with the cherty quartz, which appears to be free of the relict material.

This specimen represents one of the lowest stratigraphic occurrences of the quartz-specularite relict silicate variety, that is, the outcrop is immediately above the siliceous goethite mineralogic variety in the lower sub member of the lower Wabush Iron Formation.

The total volumetric Fe_2O_3 content of these samples ranges from 22% to 46% and the percentage of silicate mineral casts ranges from 4% to 18% with the smallest percentage occurring in the anomalous "specularite granular hematite-relict silicate" variety.

Very Fine-grained Hematite: microscopic examination of this material indicates that it is a highly ferruginous chert with minor quantities of quartz with indistinct grain boundaries. The chert commonly carries normal sized inclusions of specularite and less than .05 millimeter sized ferruginous particles. The best example of this mineralogic variety is found in sample No. 65 (Figure 12). This specimen exhibits a micro-crystalline cherty matrix containing aligned .3 - .5 millimeter bands of ferruginous grains about 1.0 millimeters apart. The iron minerals in these bands occur in two sizes. The larger grains are specularite, and average 1. x .6 millimeters in size, whereas the smaller grains, which range in size from about .005 to .01 millimeters, cannot be definitely identified as specularite. Twenty-seven percent of the sample consists of the specularite grains and twenty-two percent consists of the extremely fine-grained material.

Q - *Cherty Quartz*
S - *Specularite*
F - *Ferruginous Inclusion*
C - *Cavity lined with Limonite*

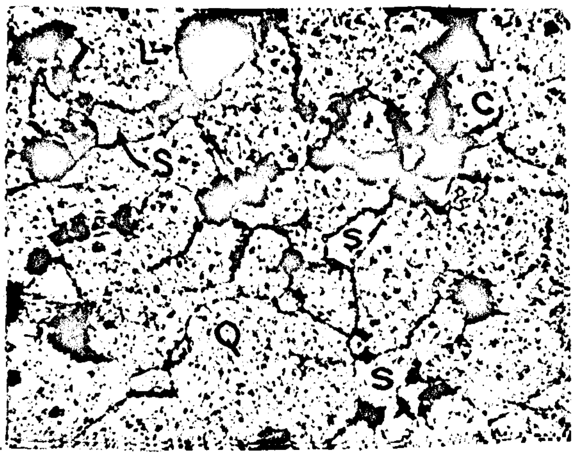
FIGURE 12
PHOTOMICROGRAPH OF SPECIMEN #65
VERY FINE GRANED HEMATITE FROM
11,430N/10,825E. MAG. 100X (APPROX)

There may be a genetic relationship between the occurrence of minute iron mineral grains in the cherty matrix and the presence of extremely fine sized ferruginous inclusions within quartz grains of other mineralogic varieties.

This variety appears to be generally free of manganese oxide (or hydroxide) because reactions to hydrogen peroxide are negative to very weak. Tests with the magnetized probe, however, indicate that the specularite grains are moderately to strongly magnetic.

The total hematite content of this material ranges from 27% to 55%. Two samples, numbers 51 and 93 contain martite and chert rather than specularite and chert with the martite content being 40% and 51% respectively.

Ferruginous Quartzite: this lean member of the iron formation exhibits a heterogeneous composition with variable amounts of quartz, martite, amorphous hematite, specularite, soft red hematite and limonite-goethite. The predominant mineral is quartz, constituting more than 80% of each sample. (Figure 13).



Q - *Quartz*
S - *Specularite*
L - *Limonite in cavity*
C - *Cavities, lined with limonite*

FIGURE 13

PHOTOMICROGRAPH OF SPECIMEN # 18
FERRUGINOUS QUARTZITE FROM
9,880 N./10,455 E. MAG. 60X (APPROX)

Martite is the principle iron oxide mineral in six of the seven samples studied, and ranges from a minimum of 8% to a maximum of 16%. Specularite (9%) is the only ferric iron mineral in the remaining sample.

The specimens are essentially free of manganese oxide (or hydroxide), only one exhibited a weak reaction to hydrogen peroxide. Responses of the martite and specularite to the magnetized probe were weak to moderate in all specimens.

The quartz grains are generally euhedral and angular, but are frequently fractured. The fractures contain limonite-goethite, amorphous hematite and occasionally specularite grains. The specularite grains in the fractures probably formed from late secondary solutions. The high degree of fracturing exhibited in this material may be due to its massive and brittle character when subjected to moderate post-metamorphic stresses.

The quartz grains range in size from .15 to .7 millimeters but average .2 - .4 millimetrs. The martite grains also fall predominantly in the .2 - .4 millimeter size range. The specularite is euhedral and tabular and its dimensions average .15 x .33-.4 millimeters.

Limonite-goethite, which occurs in only two samples, and constitutes less than 6% of the observed surface, occurs as massive blebs, fracture fillings or in vuggy zones within the quartz. Amorphous hematite, partially replaced by goethite, was observed in the sample No. 18.

Reclassification of Mineralogic Types

The polished section study revealed that the megascopic classification was reasonably correct. This is especially true in reference to the *quartz-specularite-relict silicate*, *quartz-specularite-manganese oxide*, and *very fine-grained hematite* varieties. Microscopic examination, however, showed that the specular and granular forms of hematite were intermixed more frequently than could be determined by hand specimen classification. The reason for this is that in the subjective megascopic estimation of the granular hematite content of a hand specimen, the granular hematite was often unrecognizable, or in such small quantities that it was considered to be insignificant. Thus a hand specimen or outcrop classified as quartz-specularite on the basis of a megascopic examination, could actually contian up to 10% - 15% granular hematite.

In order to attain definitive microscopic terminology, for example, *quartz-specularite* containing only quartz and specular hematite, the writer has selected certain arbitrary mineral content limits and has reclassified the microscopic specimens accordingly. This step was also necessary to ensure that the iron minerals in the specimens selected for testing in the magnetic susceptibility meter would be known to be specularite, granular hematite or a mixture of the two forms.

The following criteria were utilized in order to place a given specimen in a particular category.

1. Quartz-specularite:

   The presence of quartz, specularite, minor secondary iron oxides, and less than 1% of either martite or amorphous hematite.

2. Quartz-granular hematite:

   Quartz, martite, amorphous hematite, secondary iron oxides and less than 1% specularite.

3. Quartz-specularite, granular hematite:

   Any combination of quartz and secondary oxides, plus in excess of 1% of either specularite, martite or amorphous hematite in conjunction with the other.

4. Ferruginous quartzite:

   Any sample with greater than 80% quartz or less than 20% specularite, martite or amorphous hematite.

Attempts were made to establish different parameters such as allowing quartz-specularite to contain up to 5% martite, and quartz-granular hematite to carry up to 5% specularite; but it was realized that there would be less wholesale shifting of specimen classifications and consequent disagreement with the geologic map if the initially presented parameters were adhered to.

Following the above procedure has, however, resulted in classification changes as presented in Table III.

TABLE III

Sample Reclassification

Megascopic Identification	No. samples at start	No. changed to other category	No. added from another category	Final No. classified in category	Net change
Qtz-Spec.	35	-19	+ 4	20	-15
Qtz-Gran	13	2	14	14	+11
Qtz-Spec-Gran	25	-13	+21	33	+ 9
Qtz-Spec MnO_2	4	0	0	4	0
Spec.-Sil.	4	0	0	4	0
V.f.G. Hem	9	2	0	7	- 2
Fe-Qtz.	10	6	3	7	- 3
Total	100			100	

From the above it may be seen that the greatest number of changes occurred in the classification of the quartz-specularite (Qtz-Spec.) which lost 19 and gained four, and the quartz-specularite-granular hematite (Qtz.-Spec-Gran.) which gained 21 and lost 13.

A significant aspect of the reclassification is that seventeen of the nineteen samples of the quartz-specularite changed to another category were added to the quartz-specularite-granular hematite type. This indicates that martite and amorphous hematite occur with specularite much more commonly than hand specimen examination reveals, and suggests a former widespread occurrence of magnetite in close association with specularite.

X-Ray Determinations

X-ray powder photographs or diffraction patterns were utilized to identify the iron and manganese oxide minerals, and the iron silicate mineral found in the quartz-specularite relict silicate variety.

In order to determine if the specular hematite which reacted strongly to the magnetized probe was maghemite or if it contained magnetite, x-ray powder photographs were made of the specularite from one of the polished sections and compared with standard magnetite powder photographs and the A.S.T.M. standard hematite cards. The photographs proved that the material taken from the polished sections was hematite, with a minor amount of quartz.

X-ray diffraction determinations of the manganiferous powder fractions of samples representing outcrops at

11310N/10975E and TR 14+55/20S (numbers 1 and 3 respectively) prove this material is predominantly pyrolusite, although sample 1 also contains some birnessite.*

Powder photographs were taken of the remains of the leached silicate mineral in the *quartz-specularite relict silicate* variety but the lines were indistinct, hence unidentifiable. This material may be the remains of anthophyllite grains. Klein, (1960) identified anthophyllite in Wabush Lake Iron Formation rocks from the west side of Wabush Lake. These rocks, allowing for their unleached conditions, are very similar in appearance to the leached *quartz-specularite-relict silicate* material in the Julian deposit.

---

* Birnessite (δMnO_2) previously identified and described by Bricker (1965).

CHAPTER IV

Genetic Interpretations and Microscopic Evidence of Post Metamorphic Alteration

It is impossible to determine the original nature of the iron formation sediments because of metamorphic recrystallization. Jackson (1962) however, found evidence indicating an originally fine grained cherty iron oxide nature for the iron formation in the Neal Lake area, West of Wabush Lake. He believes that most of the hematite in the oxide iron formation is metamorphically oxidized magnetite. His work, however, was not in an area of important post metamorphic oxidation and leaching, as is the case in the Wabush and Julian Ore bodies.

The pre-metamorphised iron formation probably consisted of inter-mixed bands of cherty ferric-ferrous iron oxides, chert, and magnetite, ranging in thickness from less than 1/16 of an inch to over three inches. During metamorphism, the silica in the chert probably recrystallized as quartz and the remaining iron oxide was converted to specularite. The primary magnetite present may have been chemically stable, hence unaffected, although it may have recrystallized into larger grains.

According to Rast (1964) nucleation and the growth of new phases are vastly influenced by the strain rate under dynamic conditions. He points out that the slower the deformation, the higher the chance of new mineral species, and that the generation of a large number of crystallographic defects in the solid medium provides opportunities for nucleation. Deformation therefore creates new defects or atomic dislocations in addition to the stationary defects and dislocations. These dislocations move and interact under stress and in a dynamic situation, become the principal agencies of diffusion and transport of matter. If the deformation rate has been very slow (10^{-14} per sec.) the material will suffer syntectonic recrystallization which will depend upon diffusion. Rast (1964) further points out that the syntectonic growth of matrix formers can be demonstrated by the common observation that quartz inclusions entrapped in syntectonic garnets are usually smaller than those in the matrix, and that this indicates the progressive growth of matrix minerals during deformation. The minerals in the matrix are almost invariably recrystallized due to post deformational annealing, whereby the grain boundaries assume a regular polygonal texture. In the case of quartz, these intergrain boundaries are straight and characterized by triple junctions in the ultimate equilibrium stage. Appreciable deviation from straight boundaries suggests strain induced boundary migration.

The foregoing may be related to observations made in this study. The generally euhedral quartz grains with straight intergrain boundaries and triple boundary junctions probably indicates post deformational annealing recrystallization. The specularite-quartz boundary relationships, in which many of the specularite grains were observed to be fitted around and adjacent to both irregular and straight quartz grain boundaries suggests that the specularite grains formed after the quartz grains. (Appendix 'C' pp.149).

The occurrence of minute (.005 - .01 mm) ferruginous grains in the cherty matrix of a sample of fine grained hematite, specimen number 65 (Figure 12) may be genetically related to the presence of extremely small ferruginous inclusions within individual quartz grains in other mineralogic varieties. That is, a very minor amount of iron oxide or specularite may have been trapped in the syntectonically crystallized quartz grains, whereas the greatest proportion of the iron oxide (possibly immiscible with quartz) was being formed into specularite crystals in a matrix composed of discrete quartz and specularite grains.

Knowles (1967) points out that the problem of coexisting magnetite, martite and specular hematite had not been sufficiently studied to determine criteria to distinguish metamorphic hematite from martite, and until these criteria are found, the problem of oxygen availability during metamorphism must be left open.

The microscopic observations suggest that the martite-amorphous hematite formed after metamorphism, and the observed relationships are discussed in the following section.

The Wabush and Julian ore bodies differ from other deposits of metamorphosed iron formation in the southern Labrador trough because they are essentially void of magnetite and because they exhibit megascopic evidence of post metamorphic oxidation and leaching. Most of the other deposits in this region contain quartz, specularite and up to 30% magnetite, and are unleached and essentially free of secondary iron minerals.

The megascopic features in the Julian deposit which indicate oxidation and leaching to depths greater than 700 feet (diamond drilling evidence) are the presence of bands of leached silicate mineral relicts, limonite-goethite and soft red hematite coatings in vugs and lense shaped solution cavities and the virtual absence of magnetite. Many of these features have been observed on a microscopic scale in the polished sections, and provide further evidence of oxidation and leaching.

The presence of granular hematite which has been determined to be a mixture of martite and amorphous hematite is the most important feature observed in the polished sections, and the one which is significantly related to the virtual absence of magnetite in hand specimens and polished sections.

The close spatial association of martite and amorphous hematite in Julian ore specimens indicates that magnetite was formerly an appreciable constituent of the deposit. The magnetite was probably co-existent with metamorphically formed specularite but because it is unstable in the presence of O^- under certain geochemical conditions (specularite is stable in the presence of O^-), it was easily post metamorphically oxidized to martite.

The amorphous hematite may have been martite which was dissolved and then redeposited without observable crystal form, or it may have been formed directly from magnetite without frist becoming martite. If the latter is the case, amorphous hematite may have formed in an O^- rich dynamic open system whereas the martite may have formed when there was no movement of material other than the addition of O^-.

The polished section study strongly suggests that amorphous hematite is dissolved and redeposited martite, although only 15-20 cases were observed in which portions of martite grain boundaries merged imperceptibly with amorphous hematite. Nearly every specimen of *quartz specularite-granular-hematite* however, exhibited examples of micro veinlets and stringers of amorphous hematite leading out from amorphous hematite masses and filling fractures and grain boundary irregularities in, and forming a cement between individual specularite, martite and quartz grains. The presence of isolated euhedral quartz grains completely surrounded by masses of amorphous hematite as observed in many specimens of quartz-specularite-granular hematite also suggests that the amorphous hematite formed after the metamorphically recrystallized quartz grains.

Additional evidence of post metamorphic oxidation and leaching is the presence of the leached silicate mineral casts in the quartz-specularite-relict silicate variety. This relict material probably represents former anthophyllite crystals. It is not known whether the anthophyllite is due to an original abundance of magnesium in certain restricted stratigraphic horizons, or if it is the result of magnesium ionic mobility associated with severe deformation during metamorphism. (The anthophyllite bearing rocks are commonly the most severely deformed). However, if the presence of anthophyllite is due to magnesium ionic mobility during deformation, it should be more widely distributed through other stratigraphic horizons, but it is essentially confined to one horizon and it is always associated with specularite.

The stratigraphic position and mineralogic association therefore, suggest that certain stratigraphic horizons contained an abundance of magnesium bearing minerals.

Further evidence of post metamorphic leaching and oxidation has been observed as the presence of limonite-goethite and soft red hematite as a coating in vugs and cavities and as veinlets filling micro fractures. The limonite-goethite may be the resulting product caused by the conversion of some of the specularite or martite amorphous hematite. The lensoid form of many cavities which were observed to be abundant in the polished sections suggests that they were caused by the leaching out of a carbonate mineral. Knowles (1957) determined that similarly shaped cavities in the Wabush ore still contain a few carbonate minerals.

The extreme friability of many ore specimens is further evidence of post metamorphic leaching. This feature may be due to the removal of fine grained siliceous cementing material in certain stratigraphic and/or mineralogic units. Knowles (1955) suggests that the hydrous solutions involved in leaching were of meteoric origin and that the iron formation was at one time slightly permeable and fractured. This condition allowed the downward percolation of surface waters which may have become slightly acidic by taking carbonate into solution. These slightly acidic solutions were able to dissolve additional carbonate minerals and even much of the siliceous cement. He also suggests that the goethite in the siliceous goethite mineralogic variety, which occurs in the lowest stratigraphic sub member of the lower Wabush Lake iron formation in the Wabush deposit, has been introduced by solutions descending from the overlying iron formation.

Limonite and soft red hematite commonly occur as coatings on quartz, specularite and martite grains, and minor amounts of manganese oxide or hydroxide occur in the inter granular areas of many specimens. These features indicate that iron and manganese bearing hydrous solutions migrated through the deposit after the formation of quartz, specularite and martite grains.

CHAPTER V

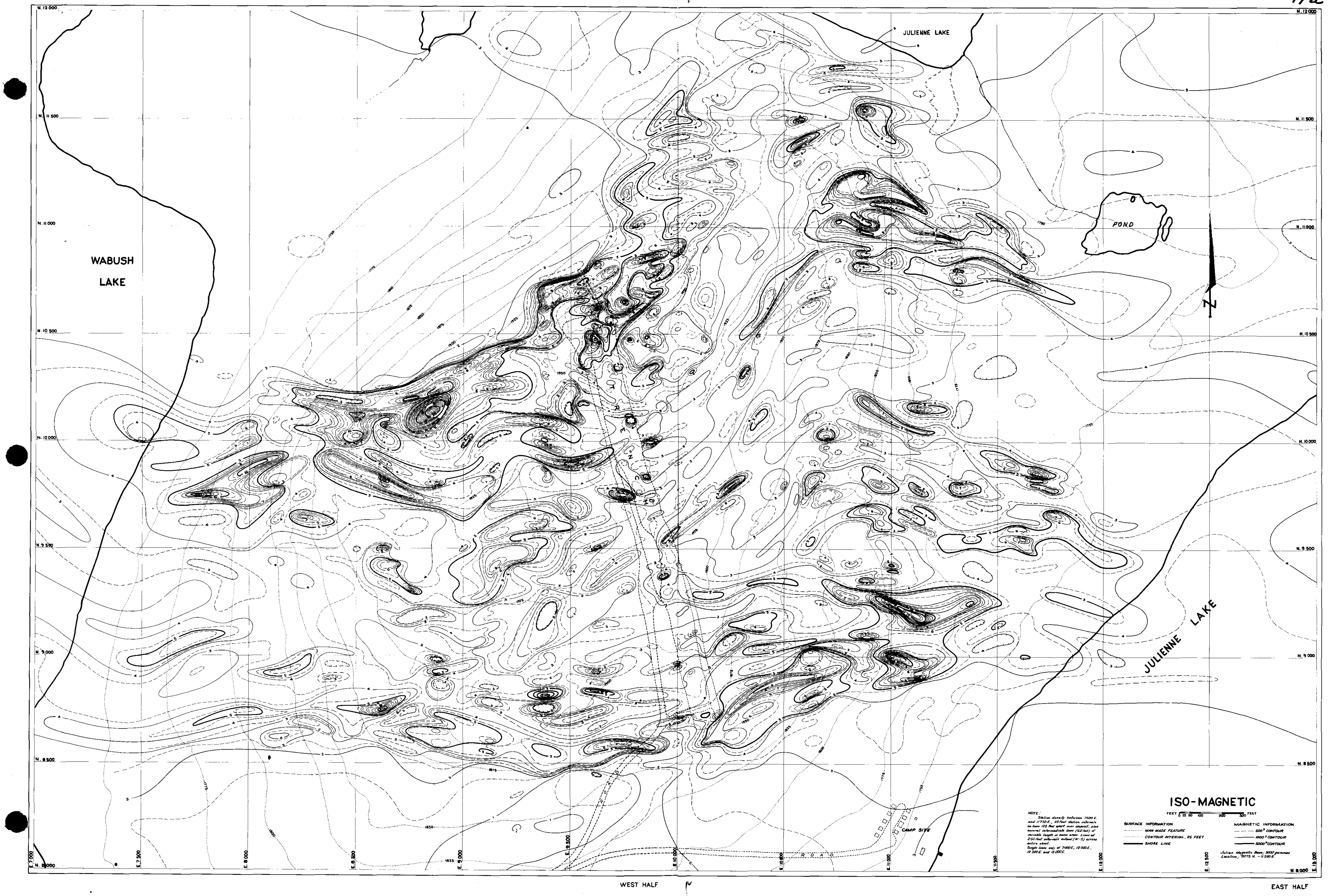
Magnetic Investigation

Investigations of the magnetic properties of the iron and manganiferous minerals were conducted on the unused portions of twenty five samples which had been examined in polished section. The objective was to determine the relationships between mineralogy and magnetic susceptibility and to determine if similar relationships also appear between mineralogy-stratigraphy and the ground magnetic survey over the deposit.

The accompanying iso-magnetic maps (Figure 14 and Plate II) have been prepared from surveys conducted in 1962 and 1963 with a Jalander model 1957, vertical field fluxgate magnetometer. This instrument may be operated rapidly and has a maximum sensitivity of 10 gammas per scale division. All of the instrument readings were corrected for diurnal and day to day variations expressed relative to a magnetic base (located at 8250N/11500E) with an arbitrary value of 3000 gammas. The corrected values have been contoured at 500 gamma invervals on the accompanying maps.

The tests performed with a magnetized dental probe on powder scratched from the iron oxide minerals in the

7/a



ISO-MAGNETIC

FEET 0 25 50 100 200 300 FEET

SURFACE INFORMATION
- MAN MADE FEATURE
- CONTOUR INTERVAL, 25 FEET
- SHORE LINE

MAGNETIC INFORMATION
- 500γ CONTOUR
- 1000γ CONTOUR
- 5000γ CONTOUR

Julian Magnetic Base; 3000 gammas
Location; 8275 N. – 11 250 E.

NOTE:
Station density between 7500 E. and 11750 E., 25 feet station intervals on lines 125 feet apart over deposit, plus several intermediate lines (62 feet) of variable length in same area. Lines at 250 feet intervals extend (N–S) across entire sheet.
Single lines only at 7000 E., 12 000 E., 12 500 E. and 13 000 E.

polished sections (described in Chapter III) have indicated that the magnetic susceptibilities of these minerals differ between samples.

In order to consider the magnetic relationships, one must be aware that many variable properties combine to influence the response of a vertical field magnetometer at any one location. The most important property affecting a magnetometer is magnetic susceptibility, k, which is defined by Lindsley et al.(1966) as the ratio of intensity of magnetization, I to the magnetizing field, H. Thus, susceptibility k, = I/H in respect to a unit volume. Lindsley et al (1966) point out that most minerals are paramagnetic and diamagnetic with positive or negative susceptibilities of approximately 10^{-6} c.g.s. units, and Howell (1959) gives the magnetic susceptibilities of magnetite, hematite and quartz as; .3, .003 and .000001 electromagnetic c.g.s. units respectively.

Other important properties affecting the response of a magnetometer are polarization and permanent magnetization. Because these properties are randomly distributed in a rock and because of the spatial relationship and the inverse square of the distance effect between the rock and a magnetometer the instrument records only the summation of the vertical fields produced by an infinite number of heterogeneously distributed variably susceptible, polarized and permanently magnetized particles in a hemispherical volume of rock of unknown size.

Previous magnetic surveys on the Wabush Lake and Julian orebodies have indicated that the higher magnetic responses are associated with the presence of specular hematite in nearby outcrops. This suggested that a closely spaced magnetic survey might reflect the surficial mineralogic distribution in areas of shallow overburden.

The 1963 magnetic survey was conducted to test the idea of a mineralogy-magnetic response relationship. The magnetometer station density was successively increased until it was determined that readings taken at 25 foot intervals could produce profiles reasonably representative of the actual profiles. This was based on tests made in several locations by taking magnetometer readings at 5, 10, 25 and 50 foot intervals across several hundred feet of iron formation. Test readings taken at 25 foot intervals produced meaningful profiles, and this is probably partly due to the widths of individual stratigraphic bands, because over 70% of the outcrop cross section exposed in the bulldozed area consists of individual bands twenty five feet or more in width.

The deposit was initially surveyed at 25 foot station intervals on north-south grid lines 250 feet apart. Correlations between lines were doubtful in some areas however, so intermediate lines 125 feet apart were run. This line density generally produced profiles which could be correlated, but in some instances it was necessary to run lines 62 feet apart to provide reliable inter profile correlations.

Magnetic, mineralogic and stratigraphic evidence was plotted on the profiles and geologic correlations were made between adjacent profiles. Distinct, continuous magnetic highs or lows, up to 1000 feet in length were identified which generally appeared to be related to the mineralogy in the outcrops.

The writer wishes to emphasize that it is the existence and location rather than the amplitudes of magnetic highs and lows that is meaningful on a particular profile, and that an individual profile is significant only when its pattern appears on two or more adjacent profiles.

By considering the overall picture (magnetic, mineralogic, stratigraphic and structural) the magnetic data was found to be of value in outlining the distribution of the deposits' stratigraphic units. Considered separately, neither the outcrop nor magnetic evidence is capable of delineating the surficial geology, but when magnetic and geologic evidence are considered together, a general picture emerges which is believed to reflect the surficial geology reasonably well.

Knowles (1968) studied the magnetic response-mineralogic variety relationship for 394 outcrops and determined that the 2000 - 4000γ range included most outcrops of each mineralogic variety, and that nearly all of the siliceous goethite, ferruginous quartzite, quartz-granular hematite and fine grained hematite outcrops were included in this range. He showed that ground magnetic responses of less than 4000 gammas have no mineralogic significance, but found that the presence of specularite is primarily responsible for responses above 4000γ. The current study examines the suggested relationship in terms of micro mineralogy and the magnetic susceptibility of ferruginous concentrates.

The susceptibility tests were performed primarily on hematite concentrates. This mineral normally has a magnetic susceptibility of .003 c.g.s. electromagnetic units which is two orders of magnitude less than that of magnetite.

Sample Selection and Preparation

Twenty-seven samples of different mineralogic varieties were selected to represent outcrops over which the magnetic responses varied from 1000γ below to 18,000γ above the 3000γ background. The samples selected, mineralogic type and ground magnetic value, (based on the proximity of the outcrop to an isomagnetic contour line of a given value,) are presented in Table IV.

In reference to the "Ground Magnetic Value" column in Table IV the writer wishes to emphasize that the magnetometer stations may be up to 75 feet away from the outcrop from which a selected sample was taken, and because the contour lines near the outcrop have been drawn between stations, the iso-magnetic contour lines nearest to a given outcrop represent the closest approximation of a reading which might be obtained if taken directly over the outcrop.

TABLE IV

MAGNETIC SAMPLE INFORMATION

Test Sample Number	Map Location	Mineralogic Type	Ground Magnetic Value γ
M-1	9895N/9500E	V.f.gr. Hem.	10,000
M-2	11430N/10825E	V.f.gr. Hem	3,500
M-3	11310N/10975E	Spec.-Pyro.	3,000
M-4	9080-9090N 107506	Spec.-Pyro.	4,000
M-5	Tr 21+00 - 21+50 C L	Spec. Sil.	9-10,000

M-6	11100N/11215E	Spec. Sil.	3,500
M-7*	11020N/11100E	Fe QTE.	-----
M-8*	10500N/10106E	Fe QTE.	-----
M-9	9815N/8580E	Qtz.-Spec.	9,000
M-10	9745N/8660E	" "	6-7,000
M-11	8615N/8745E	" "	3-3,500
M-12	11150N/10975E	" "	8,500-9,000
M-13	10710N/11050E	" "	3,000
M-14	10105N/10990	Qtz. Gran.	6,500
M-15	9555N/8690E	" "	3-3,500
M-16	9880N/10930E	" "	4,500
M-17	8820N/9375E	Qtz. Spec.	21,000
M-18	8675N/9025E	Qtz. Gran.	5,000
M-19	8695N/8320E	" "	1,500-2,000
M-20	9700N/8090E	Qtz.-Spec. Gran.	6,000
M-21	9255N/9375E	" " "	1,000
M-22	8565N/9700E	" " "	5-5,500
M-23	TR 7+15/30N	" " "	3,000
M-24	8775N/10385E	" " "	6,000
M-25	11110N/11060E	" " "	6,000
M-26	11090N/11040E	" " "	4,000
M-27	10900N/10985E	" " "	5,000

---

*Test Samples M-7 and M-8 were not run because the specimens did not contain sufficient iron oxide minerals to provide the amount of concentrates required for the susceptibility meter tests. The total number of samples therefore was 25 rather than 27.

The magnetic susceptibility tests were conducted on the ferruginous or manganeferous fraction of each sample which had been crushed and pulverized down to -30 +120 Tyler standard screen size. A Frantz Isodynamic Separator (Figure 15) and heavy liquids were used to remove the desired material from the crushed sample.

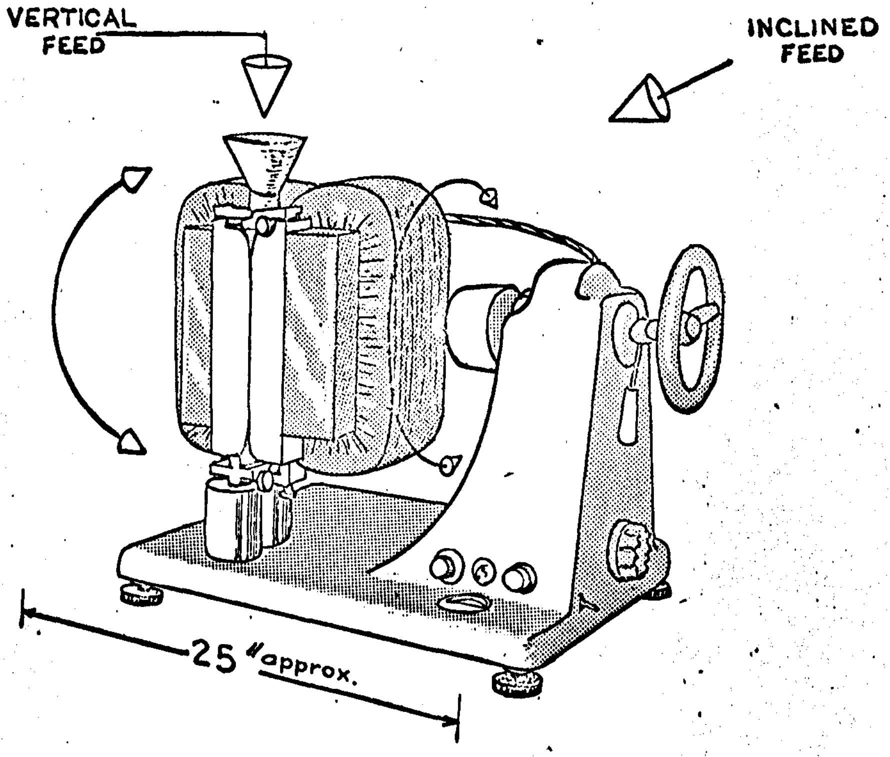


FIGURE 15

FRANTZ ISODYNAMIC SEPARATOR

Twenty-five duplicate 30 gram samples of the pulverized ore were weighed out on an analytical balance. There was not sufficient raw sample in numbers M-12, M-15, and M-19, however, to obtain 30 grams for the check samples.

Determinations of Magnetite Content: Because each sample might possibly have contained a small percentage of magnetite, and was known to contain iron filings from the pulverizer each sample was passed through the magnetic separator, set up in the vertical configuration (recommended by the manufacturer and Hess (1959) to remove this material which would contaminate the hematite sample to be tested in the magnetic susceptibility meter.

All of the samples were passed through the isodynamic separator in the vertical configuration with a .05 ampere power setting until they were cleaned of magnetite and iron filings. The face of the separator was shielded with Herculene drafting film, fastened to the unit with scotch tape to prevent fouling the magnets with this material which might contaminate subsequent samples. Usually five or six repetitions were sufficient to remove the magnetite and iron filings from a sample. This fraction was passed through the unit three or four times until it was cleaned of dust and hematite, then saved and weighed.

This step determined that the variations in ground magnetic response are not attributable to the presence of appreciable amounts of magnetite in the ore because the combined magnetite-iron filings fraction constituted more than 1% in only two samples, e.g. M-2 - - 1.02% and M-16 - - 1.29%. This fraction varied from a minimum of trace amounts to a maximum of .70% in the remaining 23 samples. This indicates that the ground magnetic responses recorded over the Julian deposit are due to unusual magnetic characteristics of the hematite in the ore.

After removal of the magnetite-iron filings fraction from the raw sample the quartz-hematite fraction was sieved to -30 +40 mesh, -40 +100 mesh, and -100 +120 mesh and each size fraction was passed through the isodynamic separator set up in the normal configuration. The sieving was necessary to provide a uniform grain sized feed, essential for the efficient operation of the Frantz unit. The concentrates from each size fraction were combined and retained for the susceptibility meter tests.

The Frantz Isodynamic unit effectively separated the hematite from the non magnetic material in 11 of the 25 samples. The remaining samples would not separate cleanly even after many adjustments were made with forward and side slope, feed rates, vibration and power settings. The major problem was that a clean magnetic concentrate could not be obtained because most of the quartz grains were drawn to the magnetic side of the unit, possibly due to the presence of ferruginous inclusions. Bromoform, (specific gravity 2.85) and methyline iodine (specific gravity 3.3) were used to obtain quartz free concentrates for the susceptibility meter whenever a clean separation could not be made on the Frantz Isodynamic unit.

Fifteen gram samples of concentrate contained in 2 dram bottles were used in the susceptibility meter and whenever the original sample did not provide sufficient concentrate, a separation was made from the duplicate sample and the two concentrates were combined.

It should be noted that there was no practical means of separating the specularite, martite and amorphous hematite particles from the finely pulverized material, therefore, the magnetic susceptibility measurements of some samples are made on mixtures of these forms. However, the ratios between these components within a specific sample are assumed to be approximately as determined from the polished section point counts.

The Magnetic Susceptibility Meter

The practicality of employing an electronic device to measure the degree of magnetic susceptibility in mineral samples was confirmed by Dobrin (1952), who briefly described an alternating current susceptibility meter assembled by

W. M. Barret (1947) and described in detail in "Early Geophysical Papers", Society of Exploration Geophysists 1947. Consultation with personnel at the University of Vermont Instrumentation and Model facility determined that a similar device could be constructed by them. A wiring diagram and essential operating instructions are included as Appendix D.

The apparatus consists essentially of a transformer, millivolt meter, wheatstone bridge and potentiometer. The method of operation consists of adjusting the potentiometer and mechanically positioning an iron bar to null the two magnetic fields, then inserting the sample in one field. The difference in the strengths of the two fields caused by the presence of the sample, is expressed as a current change which is increased 10^4 times to be read on the millivolt meter.

The upper and lower limits of the meter's required range were established by using ten 15 gram samples of powdered quartz containing 1% through 10% pulverized (Kiruna) magnetite. These 10 standard magnetite samples were tested several times, resulting in the calibration curves of magnetite content against changes in millivolt meter scale readings presented in Figure 16 .

In order to be assured that the instrument could effectively differentiate between the different magnetic

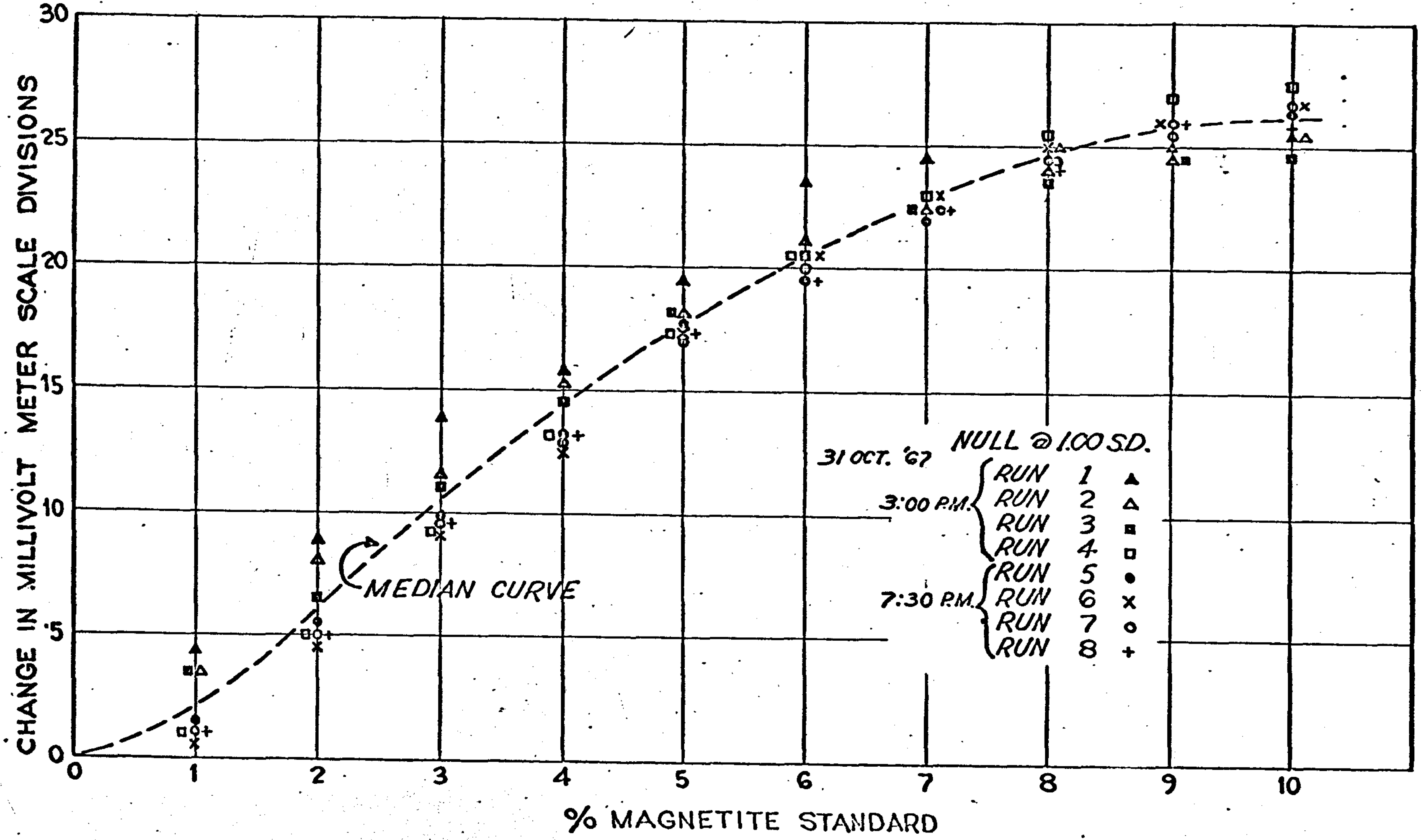


FIGURE 16

MAGNETIC SUSCEPTIBILITY METER TEST CURVE susceptibilities of Julian ore concentrates, experiments were conducted with the concentrates of ten different specimens. Each was split into four 15 gram portions placed in 2 dram bottles and tested in the susceptibility meter. This procedure determined that all of the test samples produced changes of 3 to 12 millivolt meter scale divisions. Most of the concentrate samples to be tested in the formal runs, therefore, could be expected to fall within these limits.

The foregoing tests, however, also showed that a sample tested ten times within 10 minutes would produce a response of 5 scale divisions each time, but that one hour later, ten tests of the same sample might produce responses of 8 scale divisions. This indicated that the responses obtained for the same sample, tested at different times could not be compared numerically. These variations were caused by irregularities in the power supply. A voltage regulator was added to the instrument to compensate for this but it greatly reduced the instrument's sensitivity, and therefore had to be removed.

Procedures: the ratio system described below was devised in order to obtain reproducible results from the susceptibility meter.

Most of the samples could be expected to produce changes of 3 - 12 millivolt scale divisions and the value of the 2% magnetite standard always fell within these limits. Therefore, all of the samples were compared with this standard and the absolute numerical value of the millivolt scale reading was considered to be meaningless. Theoretically, any changes in the power supply should affect the standard and the test sample to the same degree, and the relationship between the response of the sample and that of the standard should be constant. For example; the values obtained for sample"X" and the 2% magnetite standard at time'A' might be 3 and 6 scale divisions respectively. The ratio of the $\frac{\text{sample}}{\text{standard}}$ then $= \frac{3}{6} = .5$. At time 'B' the values of sample "X" and the standard may be 5 and 10 scale divisions respectively. The relationship between them, however, remains .5.

The operating procedure developed through experimentation was to insert the 2% magnetite sample, record the reading and immediately insert the test sample and record the reading. In this manner a reproducible ratio could generally be obtained with several readings between the sample and the 2% magnetite standard.

The problem of power line surges was largely compensated by conducting the formal runs during periods of off peak power loads, such as late in the evening or on Sunday afternoons.

However, the susceptibility meter was subject to power line fluctuations which could not be eliminated. As a result, the ratio of a given sample compared to 2% magnetite was never absolutely identical for repeated runs, that is, it might vary from .35 - .45, or .75 - .90. Therefore, a method of expressing the ratio was arbitrarily established which would include all of the ratio variations of any one sample. This method allows a ratio obtained on any test to fall within one of eight one quarter ratio units (ranges) of the sample compared to the 2% magnetite standard as per Table V. Thus, range IV represents a ratio value twice as great as range II and range II represents a value twice as great as range I, etc.

The ranges have been established as follows:

TABLE V

RATIO VALUE RANGES

Range	Ratio, sample compared to 2% magnetite
I	0.00 - 0.25
II	0.26 - 0.50
III	0.51 - 0.75
IV	0.76 - 1.00
V	1.01 - 1.25
VI	1.26 - 1.50

VII	1.51 - 1.75
VIII	1.76 - 2.00

With ratio variations of up to .15 units, it is realized that two samples classified in adjacent ranges may not necessarily have different susceptibilities. Two samples are significantly different, therefore, only when they are separated by one or more ranges.

Bacon (1957) found that uncrushed samples of Wabush ore had a definite polarization direction and the Julian ore probably has this same property. The concentrates tested in the susceptibility meter consisted of randomly oriented ground material, therefore, there was no means of testing for a polarization direction. Several bottles of concentrate were thoroughly shaken, rotated and tested repeatedly. The resulting readings were identical within the limits of the device. This indicates that polarization effects were not present, and that the strength of the field created by the susceptibility meter was not sufficient to reorient the particles.

Six formal runs were made with each sample and the results are presented in table VI. The Data sheet for the formal runs is included as Appendix E, and the magnetic sample numbers, mineralogic varieties and locations are indicated on the large scale Isomagnetic Map (Plate II).

Results of Magnetic Susceptibility Investigation

The results of these investigations are presented in table VI which shows the variation in the degree of magnetic susceptibility obtained for each sample. The ratio values extend from a low of range I to a high of range VIII.

In reference to the first question regarding the magnetic problem (page 3):

> "Is there a direct relationship between the magnetic susceptibilities and mineralogy of selected samples?"

The first observation is that definite magnetic property differences exist between the samples. With the exception of number M-19*, all of the samples consist of 15 (accurately weighed) grams of the magnetic or heavy liquid ferruginous concentrates, undiluted with quartz or other light or non magnetic minerals, and uncontaminated by magnetite or iron filings. The ratio value ranges, therefore, represent the mangetic character of the hematite, goethite-limonite and pyrolusite fractions only, and are not directly applicable to the rocks represented by a particular sample.

The most important observation noted in these investigations, and the key to the unusual magnetic features of the

---

*Due to lack of material, this sample consisted of 14.25 grams of concentrate, thus the recorded range value may be slightly low.

TABLE VI

RECAPITULATION OF MAGNETIC DATA

	SAMPLE NO.	GROUND MAG. VALUE (GAMMA)	WEIGHT MAG'TE AND IRON FILLINGS	% MAG'TE AND IRON FILLINGS	% SPEC. BY POINT COUNT	% MARTITE BY POINT COUNT	TOTAL % Fe_2O_3 POINT COUNT	% LIM./GOET. BY POINT COUNT	% MnO_2 BY POINT COUNT	% OTHER BY POINT COUNT	RATIO VALUE RANGE	REMARKS
HARD, V. FINE GR. HEM.	M-1^A	10,000	.172	.57	-	33.1	33.1	25.5			IV	Combined Mag. Concentrate
	M-1^B	10,000			-	-	-	-	-	-	I	Mag. Tails Sample 1A = Lim/Goet.
	M-2	3,500	.306	1.02	26.6	21.6	48.2	-	-	-	IV	Comb'd, Heavy Liquid Conc.
SPECULAR MANG. OXIDE	M-3^A	3,000	.189	.62	42.0	-	42.0	-	29.4	-	III-	Combined, Mag. Concentrate
	M-3^B	3,000									I	MnO_2 Fraction of M-3^A
	M-4^A	4,000	.035	.016	26.8	2.0	28.8	-	14.8	-	I	Mag. Conc.
	M-4^B										I	MnO_2 Fraction of M-4^A
SPEC. SIL.	M-5	9,000 10,000	.011	.037	34.8	-	34.8	-	-	CASTS 17.0	IV	Mag. Concentrate
	M-6	3,500	.011	.037	46.6	-	46.6	-	-	CASTS 18.2	VII	Mag. Concentrate
QTZ.- SPECULAR	M-9	9,000	.016	.053	55.6	-	55.6	-	-	-	IV	Mag. Concentrate
	M-10	6,000 7,000	.080	.267	37.0	-	37.0	-	-	-	IV	Mag. Concentrate
	M-11	3,000 5,000	.080	.267	47.0	-	47.0	-	-	-	II	Mag. Concentrate
	M-12	8,500 9,000	.011 .010	.037 .030	25.2	-	25.2	-	-	-	VI	Comb'd, Heavy Liquid Conc.
	M-13	3,000	.052	.173	29.2	-	29.2	-	-	-	IV	Comb'd, Heavy Liquid Conc.
	M-17	21,000	.178	.295	63.6	-	63.6	-			VIII	Mag. Concentrate
QTZ.- GRANULAR	M-14	6,000	.084	.258	TR.	41.4	41.4	-	-	-	I	Mag. Concentrate
	M-15	3000 3,500	.100	.333	-	47.4	47.4	-	-	-	II	Mag. Concentrate
	M-16	4,500	.388	1.29	-	47.0	47.0	4.0	-	-	I	H.L. Dirty Red Conc. Oxidized
	M-18	5,000	.090	.300	-	69.8	69.8	2.2	-	-	II	Mag. Conc. (Sample = 14.25 grs)
	M-19	<2,000	.030	.10	-	31.6	31.6	1.6	-	-	I	Mag. Concentrate
QTZ.-SPECULAR GRAN.	M-20	6,000	.161	.536	37.6	16.6	54.2	-	-	-	IV	Mag. Concentrate
	M-21	1,000	.038	.126	19.9	10.8	30.7	-	-	-	II	Mag. Concentrate
	M-22	5,000 5,500	.005	TR.	28.6	5.3	33.9			2NDARY HEM. 2.3	IV	Comb'd H.L. Concentrate
	M-23	3000	.030	.10	61.8	2.2	64.0	4.8	-	-	IV	Mag. Concentrate
	M-24	6000	.211	.70	29.7	46.5	20.6	-	-	-	III	Mag. Concentrate
	M-25	6000	.088	2.94	10.0	10.6	20.6	-	-	-	II	Comb'd. Mag. Concentrate
	M-26	4000	.183	.61	15.9	27.5	43.4	7.3	-	-	IV	Mag. Concentrate
	M-27	5000	.120	.40	3.8	30.8	33.8	-	-	-	II	Mag. Concentrate

NOTE: Combined Conc. = Concentrate oof Original and Duplicate Samples to Make 15 grs.

deposit is that the specularite fraction of the *quartz-specularite*, and *quartz-specularite-relict silicate* samples produced *consistently higher* and more widely distributed ratio values that the magnetic or heavy liquid concentrates from any of the other samples. (Figure 17). Thus, specularite appears to be two to four times as magnetic as the other forms of hematite. Of a total of eight samples in these two classifications, (*quartz-specularite* and *quartz-specularite-relict silicate*) four had a ratio value in range IV, one each gave a value in ranges VI, VII and VIII respectively and only one had a low response in range II.

The samples which polished section study has indicated to be composed primarily of amorphous hematite and martite exhibit low values. For example, in five samples of the *quartz-granular hematite* material, the tested fractions yielded three samples with a range I value and two with a value in range II.

The concentrates representing the ferruginous fractions of the *quartz-specularite-granular hematite* samples, produced ratio values in the intermediate area of range II to range IV. Eight samples of this material produced three ratio values in range III and four in range IV.

It is difficult to determine a direct relationship between the total amount of martite, amorphous hematite

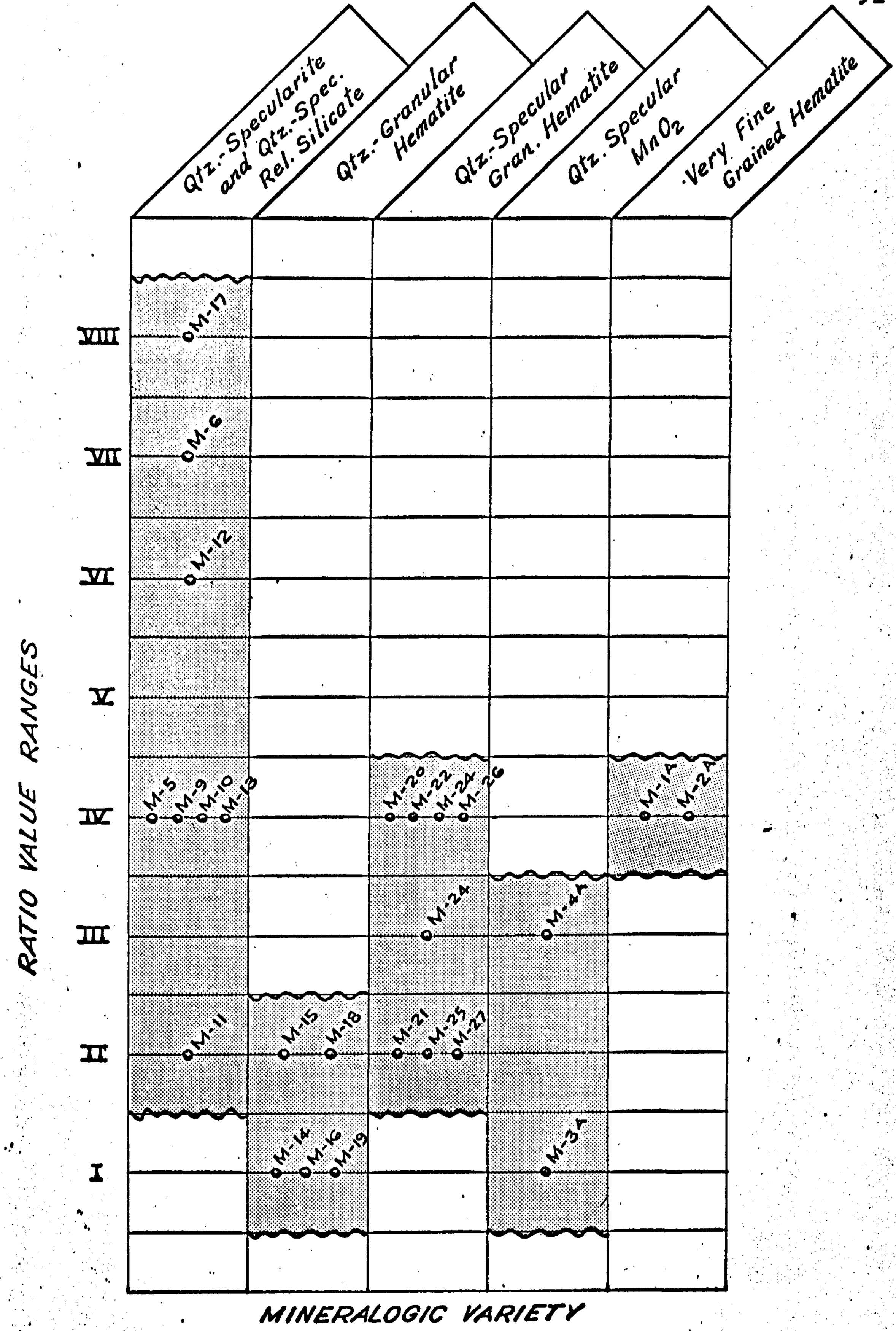


FIGURE 17

PLOT OF MINERALOGIC VARIETY AGAINST RATIO VALUE RANGES and specularite identified in the polished sections and the ratio values obtained for the concentrates of the same samples. This is illustrated in Figure 18, and Table VII. Figure 19, however, strongly suggests that there is a relationship between specularite content and magnetic susceptibility ratio values. Three of the four samples containing less than 20% specularite produced ratio values of range II whereas all of the concentrates containing greater than 25% specularite produced ratio values in ranges III and IV.

TABLE VII

RATIO VALUE RANGES FOR CONCENTRATES CONTAINING MIXTURES OF SPECULARITE AND MARTITE-AMORPHOUS HEMATITE

Sample No.	% Spec.	% Martite Amorphous Hematite	Spec: Martite Ratio	Ratio Range
M-20	37.6	16.6	2.25	IV
M-21	19.9	10.8	1.84	II
M-22	28.6	33.9	.84	IV
M-23	61.8	2.2	28.1	IV
M-24	29.7	46.5	.64	III
M-25	10.0	10.6	.94	II
M-26	15.9	27.5	.58	IV
M-27	3.8	30.0	.16	II

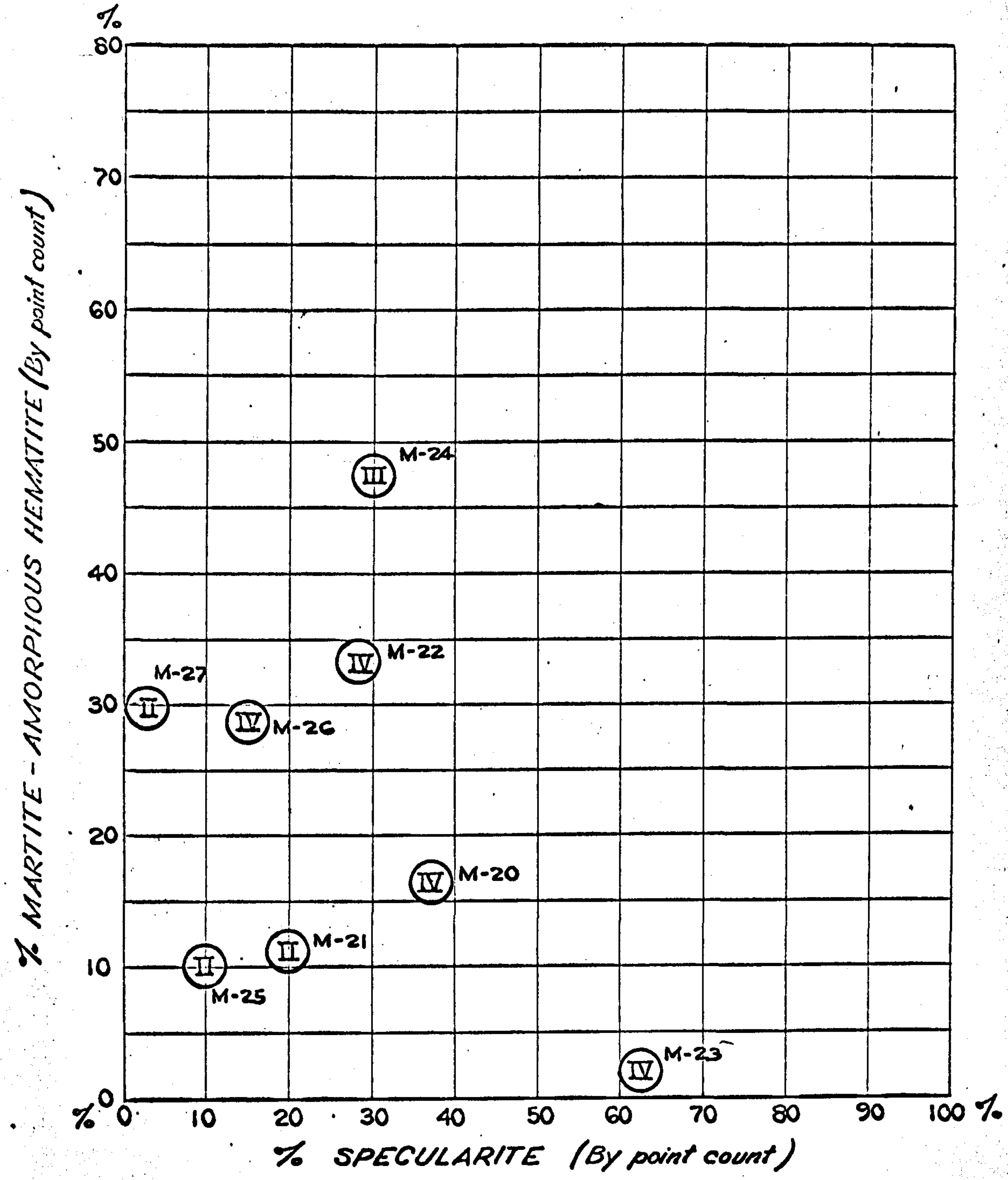


FIGURE 18

RATIO VALUE RANGES AND % MARTITE-AMORPHOUS HEMATITE AGAINST % SPECULARITE

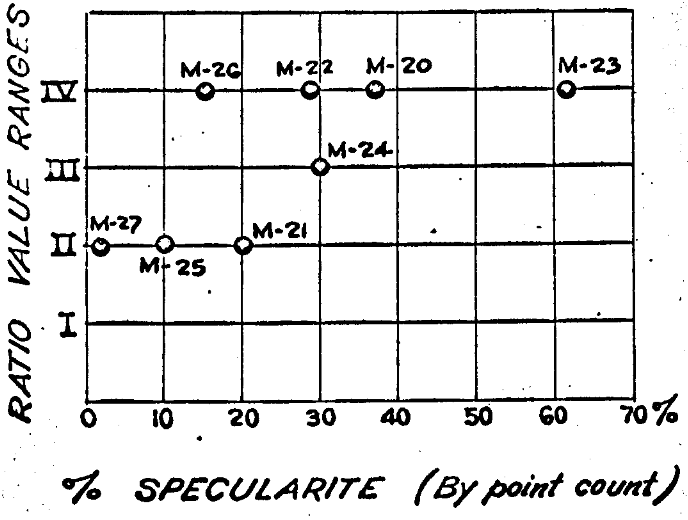


FIGURE 19

RATIO VALUE RANGES AGAINST
VOLUME PERCENT
SPECULARITE

The lower (range II) ratio value for sample M-21, which has a specularite: martite-amorphous hematite ratio of 1.84 could possibly be attributed to a combination of weakly magnetic specularite and/or essentially non magnetic martite-amorphous hematite.

The ratio values of samples M-22, M-25 and M-26 which have specularite: martite-amorphous hematite ratios of .84, .94 and .58 respectively could be attributed to different magnetic susceptibilities of the contained specularite or martite-amorphous hematite similar to the different susceptibilities exhibited by samples M-5 to M-19 inclusive, which are known to consist uniquely of either specularite or martite-amorphous hematite.

Table VI (page 89) shows that the magnetic and heavy liquid concentrates from the fine grained hematite, samples M-1A and M-2 produced magnetic susceptibility ratio values in range IV. However, polished section study determined that these two samples are mineralogically different. The ferruginous fraction in M-1A is specularite, whereas it is specularite and martite-amorphous hematite at a ratio of 1.23 in sample M-2. The fact that these two samples are mineralogically different but have magnetic susceptibility ratio values in the same range further indicates that the specularite and martite-amorphous hematite have magnetic strengths which vary from sample to sample.

The polished section study and point count of sample M-1A indicated that it contains approximately 33% martite-amorphous hematite and 25% goethite-limonite by volume. The rejects retained from the Frantz Isodynamic Separator (sample M-1B) contained quartz and goethite-limonite. These rejects wre subjected to heavy liquid separation and the recovered goethite-limonite fraction was tested in the susceptibility meter yielding a ratio value in range I (sample M-1B). This indicates that the goethite-limonite is essentially non-magnetic and as a dilutant, would probably reduce the magnetic susceptibility of a rock containing specularite and an abundance of these minerals.

Sample M-2 represents the best example of the fine grained hematite. The polished section of this material showed that it consists of a cherty quartz matrix containing normal sized grains of specularite as well as minute (.005-.01m.m.) iron mineral grains which could not be definitely identified as specularite. A clean separation of this sample was impossible with the Frantz Isodynamic Separator except for the -30 +40 mesh fraction, because the quartz particles containing ferruginous inclusions were constantly drawn into the magnetic fraction. Ultimately, a clean separation was made with bromoform. The magnetic separation problem suggests that the magnetic susceptibility of the inclusions is greater than the effect of gravity on the combined masses of the quartz particles and their inclusions.

The "quartz-specularite-pyrolusite" samples M-3A and M-4A were found in polished section to contain 42% and 28.6% specularite by volume respectively. Sample M-4A also contains 2% martite in addition to the specularite. The rejects (M-3B) recovered in the magnetic separation of sample M-3A were separated by heavy liquids and the retained pyrolusite concentrate was tested in the susceptibility meter and produced a ratio value in range I. This ratio value for the pyrolusite fraction indicates that it is essentially non magnetic.

The magnetic concentrate from sample M-4A, (Table VI, page 89) however, which has a specularite: martite-amorphous hematite ratio of 13.5, produced a magnetic ratio value of range I, indicating that the specularite fraction of this sample is also essentially non magnetic. The possibility that the lower magnetic ratio values for this sample may be attributed to contamination by inclusions or dust coatings of pyrolusite may be ruled out because polished section study has revealed that the specularite occurs as clean euhedral grains, and that the pyrolusite occurs only as a powder between quartz and specularite grains.

Other samples which were impossible to separate on the Frantz Isodynamic unit because the quartz grains were drawn into the magnetic fraction are numbers: M-12, M-13, M-14, M-15, M-16, M-21, M-22 and M-24. Of these, numbers M-12, M-13, M-14, M-15 and M-16 were found in polished section to contain inclusion-bearing quartz grains and/or ferruginous grains with quartz inclusions. The separation problem encountered with numbers M-21, M-22 and M-24 may be attributed to the prevalent soft red hematite or limonite staining of many of the quartz grains as observed in polished section.

In considering the foregoing observations, it is concluded that definite magnetic differences exist in the magnetic and heavy liquid concentrates of the crushed ore samples. Three important conclusions therefore are:

1) The specularite fraction of the quartz-specularite and quartz-specularite relict silicate varieties is from two to four times more susceptible than the martite-amorphous hematite in the quartz granular hematite variety. This conclusion is by far the most important aspect of this work. The lower (Range I and II) ratio values obtained

for concentrates of martite-amorphous hematite are probably more nearly representative of the normal magnetic susceptibility of hematite which is two orders of magnitude less than that of magnetite. These low values may also be a reflection of the normally extremely fine grain size of the amorphous hematite (individual grains in the polished sections were commonly indistinguishable under 400 power magnification) in comparison to the .2 to .6 millimeter sized grains of specularite. Lindsley, et al. (1966) report that the susceptibility of ferrimagnetic* minerals e.g. magnetite, hematite and ulvospinel, is related to grain size and that it decreases with decreasing grain size. All of the material tested in the susceptibility meter however, was greater than 120 mesh and 200 microns in size. The directly proportional decrease in magnetic susceptibility in the 200 to 500 micron range, reported by Lindsley, et al. (1966) and illustrated by the curve in Figure 20 is too slight to have been determined by the susceptibility meter utilized in this study.

---

*Ferrimagnetism differs from ferromagnetism in which all atomic spin moments are parallel in that there are two opposite but unequal sets of spins. That is, in magnetite for example, the spins of the $8Fe^{+3}$ ions in the tetrahedral positions are antiparallel to the spins of the $8Fe^{+3}$ and the $8Fe^{+2}$ ions in the octohedral positions. The moments of the trivalent ions are virtually self cancelling and the Fe^{+2} ions contribute the resultant moment. - Lindsley, et al. (1966)

It is concluded therefore that the range I and II ratio values of the martite-amorphous hematite represent the normal magnetic susceptibility of hematite, and that the higher (range IV - VIII) ratio values obtained for the specularite concentrates are due to unusual magnetic characteristics of this form of hematite in the Julian deposit. This is supported by Lindsley, et al. (1966) who report that some hematite and hematite-ilmenite solid solutions are ferrimagnetic with variations in magnetic properties which are probably due to the varying degrees of ordering of the Fe and Ti ions.

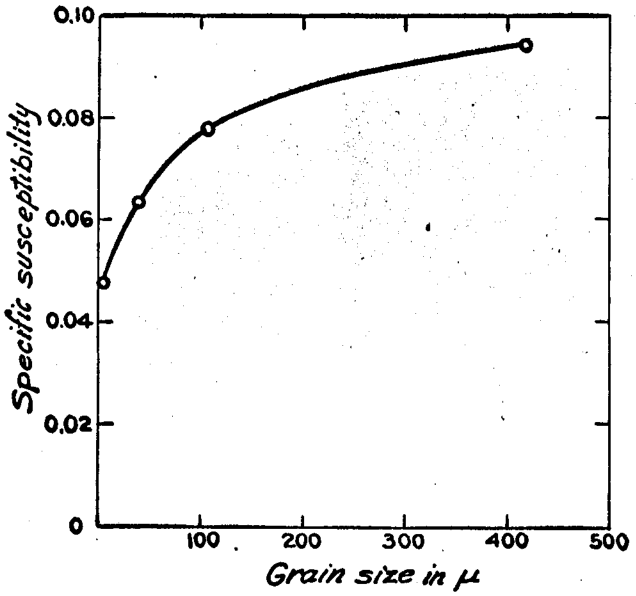


FIGURE 20

Specific susceptibility of rock-forming titaniferous magnetites as a function of particle size. External field 1.35 oe

After D.H. Lindsley et al.(1966)

2) The concentrates consisting of mixed specularite and martite-amorphous hematite from the quartz-specularite-granular hematite variety produced ratio values in the intermediate ranges of II to IV. This reflects the mixed composition of the concentrates, although the specularite: martite-amorphous hematite ratios cannot be related directly to magnetic susceptibilities on a sample to sample basis.

3) The range I ratio values obtained for the limonite-goethite and pyrolusite fractions indicate that this material is essentially non magnetic.

In reference to question number 2 (page 3):

> "Is there a definite relationship between the magnetic susceptibilities of selected samples and the outcrops which they represent?"

It should be noted that ratio values cannot be compared directly to ground magnetic responses because the ratio values represent the magnetic susceptibility of a sample consisting of 100% iron oxides whereas the ground response represents a rock containing variable amounts of iron oxides up to approximately 40% by volume. Recognizable relationships might exist however between mineralogic varieties, ratio values and ground magnetic responses and Figure 21 shows an ideal case, in which plots

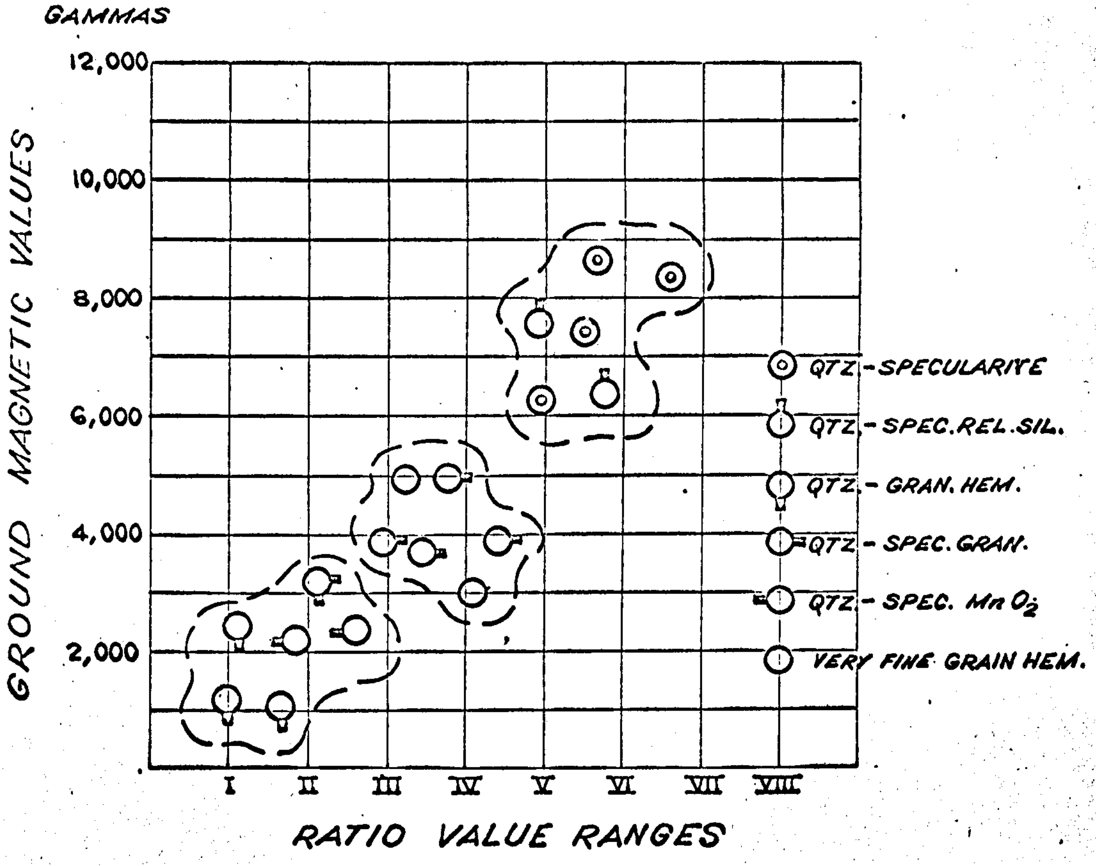


FIGURE 21

IDEAL CASE OF MINERALOGIC VARIETIES IN RELATION TO RATIO VALUE RANGES AND GROUND MAGNETIC VALUES of the mineralogic varieties are uniquely grouped along a positively sloped line between ratio value ranges and ground magnetic values.

The location of the points below the heavy dashed line in Figure 22 shows that concentrates of the samples from outcrops with ground magnetic values below 5000γ (M-4A, M-11, M-15, M-16, M-19 and M-21) are in ratio value ranges I and II. Concentrates from outcrops with values of 8,000γ - 10,000γ represented by points above the light dashed line, have recognizably higher ratio values and the concentrate from a sample representing an outcrop near the 20,000γ isomagnetic contour line (M-17) has a ratio value in range VIII. The ratio value ranges and ground magnetic values of the concentrates representing outcrops with values of 3,000γ to 7,000γ, however, are too widely distributed to be readily related.

The relationship between the magnetic susceptibility of a sample concentrate and the ground magnetic value of the outcrop from which the sample was collected must be strong and direct in order to be meaningful. That is, a ratio value of range VIII representing an outcrop with a gamma value of 20,000γ, and a ratio value of range I, representing an outcrop of 2,000γ, are considered to be meaningful relationships. However, it is significant that

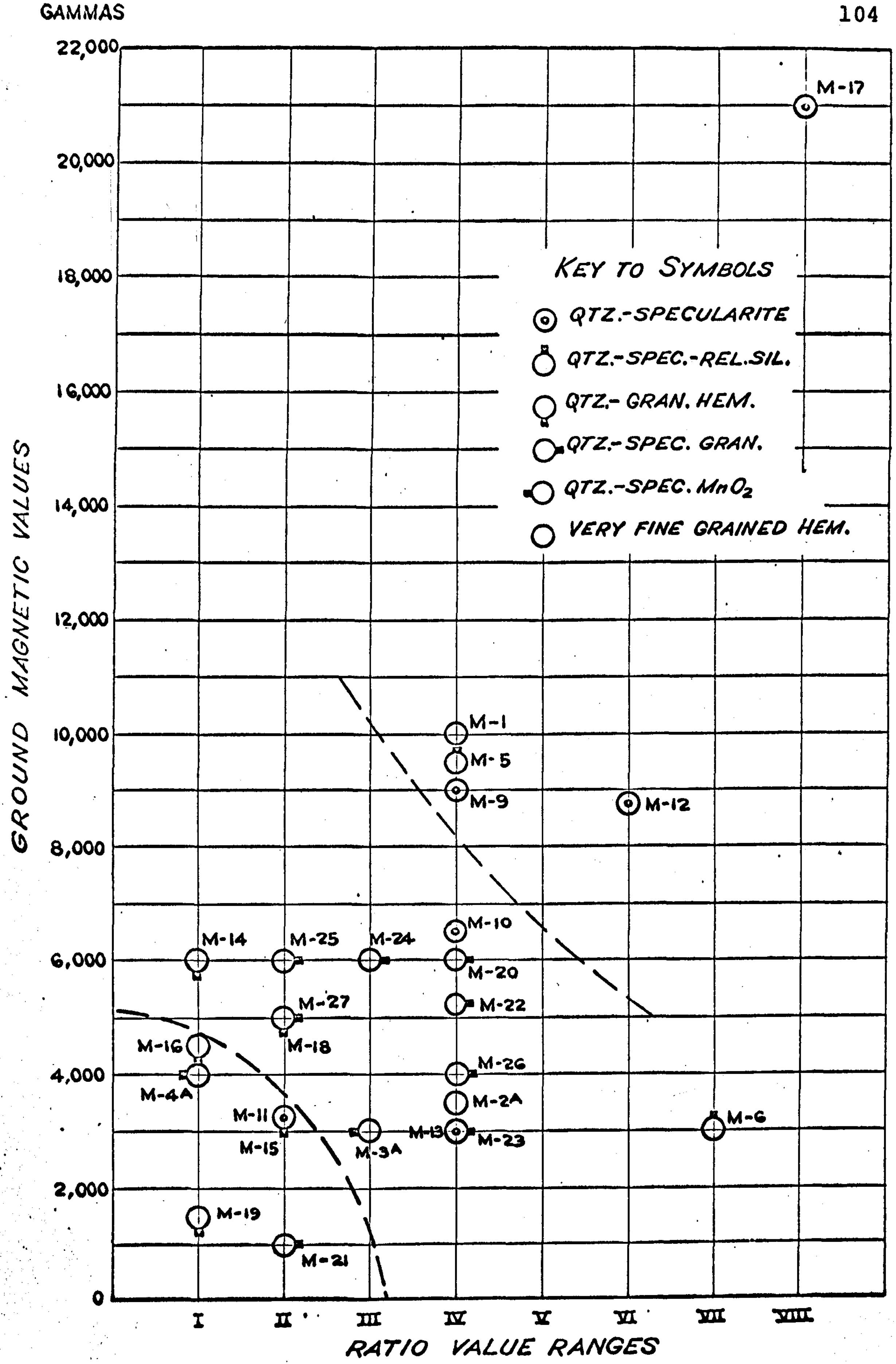


FIGURE 22

PLOT OF MAGNETIC SUSCEPTIBILITY AGAINST GROUND MAGNETIC VALUES the samples with ratio values of ranges III and IV represent outcrops with values of 3,000γ to 6,000γ.

It may be concluded from this data that a reasonable correlation exists between the outcrop gamma values and the concentrate ratio values only when the values occur at the extremes of the respective scales. In the median range direct correlations between these two measures of magnetic properties are difficult due to the variable nature of all factors involved in the outcrop gamma value and probable inconsistent, unevaluated and unaccounted for magnetic properties in the materials tested in the susceptibility meter. It is significant however, that the ground magnetic gamma values and the ratio value ranges of seven of the eight *quartz-specularite granular hematite* samples fall in the median area.

> In reference to the third question (Page 3)
> "Is there a definite relationship between
> the amounts of different iron oxides and non
> magnetic minerals in selected samples and the
> outcrop ground magnetic values?"

Figure 23 shows an ideal case in which plots of the mineralogic varieties and ratio value ranges are grouped along a positively sloping line between percentage specularite and ground magnetic values.

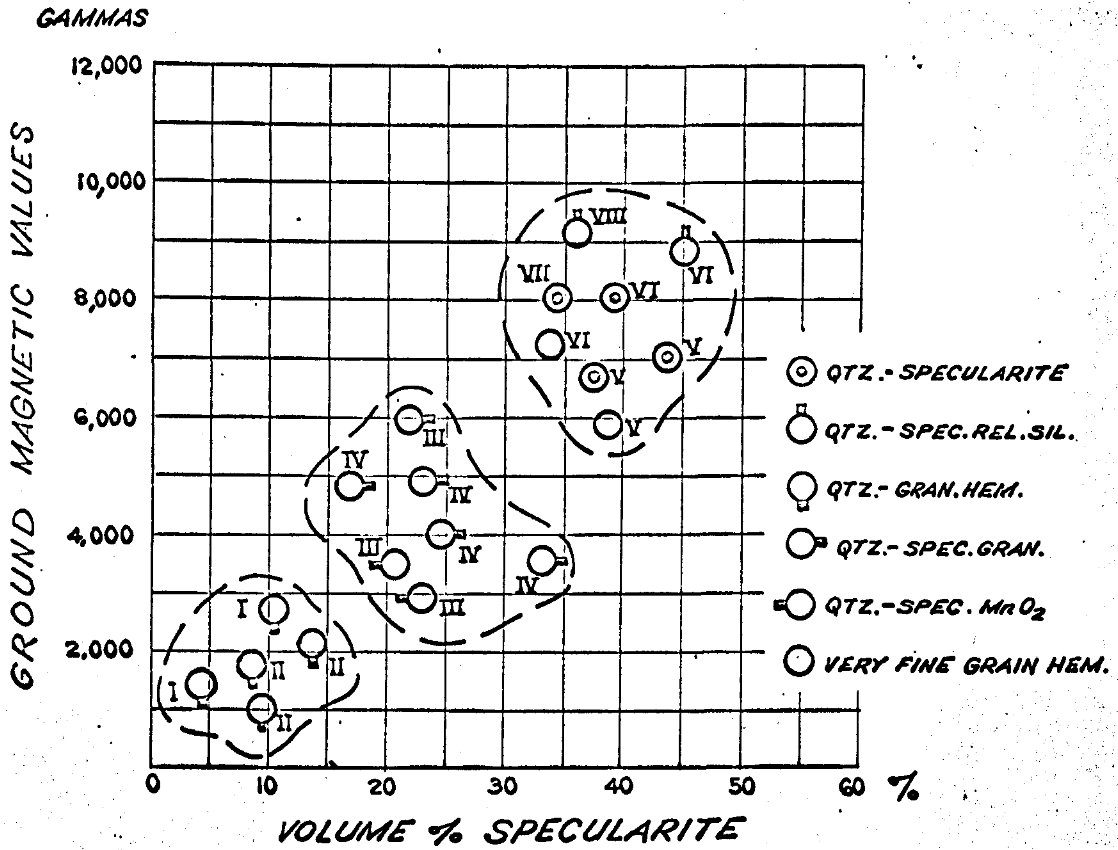


FIGURE 23

IDEAL CASE OF MINERALOGIC VARIETIES
AND RATIO VALUES IN RELATION TO
VOLUME PERCENT SPECULARITE
AND GROUND MAGNETIC
VALUES.

Figure 24 suggests that a probable relationship exists between the volume percent specularite, the ratio value range of the concentrate and the interpreted outcrop gamma values for samples: M-9, M-14, M-15, M-16, M-17, M-19, M-21, M-25, M-27 and possibly M-26.

All of the samples with a specularite content below 22.5% i.e. quartz-granular hematite and quartz-specularite-granular hematite, have ratio values of range I, II, and one of range IV and represent outcrops with ground magnetic values of less than 6,000 gammas. The only concentrate sample with a high magnetic susceptibility and specularite content representing an outcrop with a high ground magnetic value is M-17 which has a ratio value of range VIII, a 65% specularite content and a ground magnetic value of 21,000 gammas. Plots of all of the other samples however are too widely scattered to be significant, and convey little other than to attest to the variability of the magnetic susceptibility of mixtures of specular hematite and martite-amorphous hematite.

With the limited number of samples and the equipment and techniques utilized in this study, it is not possible to state categorically that there is a direct relationship between the amount of specularite of a given ratio value range and selected outcrop gamma values, which satisfactorily

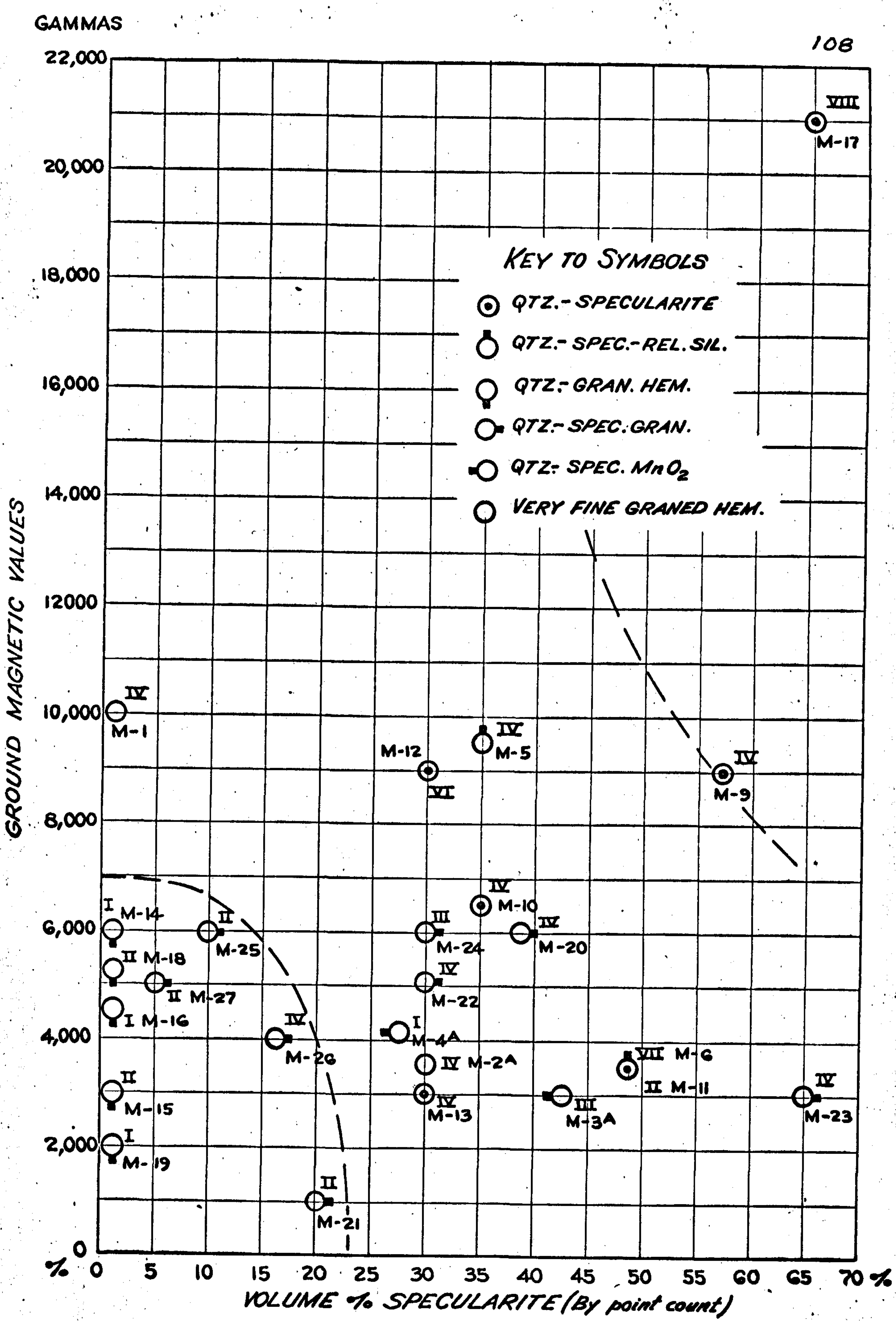


FIGURE 24

RATIO VALUE RANGES AND MINERALOGIC VARIETY
BY VOLUME % SPECULARITE (By point count)
AGAINST GROUND MAGNETIC VALUES

accounts for all samples. It is indicated however that samples with a specularite content of less than 22.5% and ratio values of range IV or less represent outcrops with ground magnetic values of less than 6000 gammas. With only one sample exhibiting a high specularite content, magnetic susceptibility and representing an outcrop with a high ground magnetic value it is not possible to make a valid correlation in respect to direct relationships. Further study, involving a greater number of samples and equipment designed to determine whole rock magnetic susceptibility might show a greater degree of correlation between these variable factors.

CHAPTER VI

Summary and Conclusions

The purpose of this study has been to investigate certain mineralogical and magnetic aspects of the Wabush Lake Iron Formation in the Julian iron deposit in southwestern Labrador. It has been concerned with a twofold problem, namely, to determine the nature and possible origin of the various varieties of iron oxide and other minerals in the ore through microscopic study of polished sections and to determine if correlations exist between the mineral content of selected ore samples, the magnetic properties of these samples, and the ground magnetic properties of the outcrops which they represent.

Microscopic Studies

The microscopic study of polished sections has provided information which may be summarized as follows:

The seven different mineralogic varieties of metamorphosed iron formation examined are from a deposit of quartz-iron oxide facies of sedimentary iron formation. The iron oxide minerals in order of abundance are; hematite, limonite-goethite and magnetite. The hematite occurs as specularite, martite, amorphous hematite, and soft red hematite.

The only accessory minerals identifiable, either by microscopic or x-ray determinations, are the manganese oxides: pyrolusite, birnessite and possibly hausmannite, and a relict silicate mineral, which probably represents a leached amphibole but which could not be identified by microscopic or x-ray means.

The most significant aspect of the microscopic examinations of the polished sections is the demonstration that granular hematite as recognized in hand specimens is probably martite occurring as individual grains and what the writer has classified as amorphous hematite, a dull gray-black form of hematite without recognizable grain boundaries.

Zones of amorphous hematite commonly contain quartz and recognizable martite grains and occasionally relict black rhombic or triangular structures which may represent former magnetite crystals, set in a matrix of gray amorphous hematite.

The presence of these relict crystal structures and recognizable martite grains in zones of amorphous hematite suggests that magnetite may have been converted to hematite in the form of martite in the late stages of metamorphism and that post metamorphic solution has destroyed most of the individual martite grain boundaries. This sequence is suggested by the presence of amorphous hematite stringers and veinlets leading directly out from solid amorphous hematite zones and filling fractures within and spaces between individual quartz, martite and specularite grains in many of the polished sections.

Individual grains of specularite, martite and quartz in all polished sections generally fall within the following size ranges:

Specularite	.15x.30, .30x.6	millimeters
Martite	.15 -.40	millimeters
Quartz	.15 -.40	millimeters

Occasionally, however, specularite grains with dimensions greater than .5 x 1.0 were observed.

Individual martite and specularite grains have been observed to be euhedral and angular with sharp intergrain boundaries except where they are in contact with amorphous hematite. In these cases the amorphous hematite has filled the irregularly shaped intergranular spaces as well as fractures or indentations on the exteriors of individual quartz, martite or specularite grains.

Quartz grains, however, range from euhedral angular to rounded, to anhedral angular to rounded and they may or may not be intergrown with each other or with hematite grains forming a mosaic pattern. The boundaries between quartz and specularite are generally clean and sharp.

Specularite grains generally exhibited a schistose arrangement in all mineralogic types. This is the most pronounced in the *quartz-specularite*, *quartz-specularite-relict silicate* and *quartz-specularite-granular hematite* varieties. Compositional layering into quartz-rich and specularite-rich bands was also noted on a microscopic scale in many polished sections of the above ore types.

Tests of powdered specularite, martite and amorphous hematite indicated that these minerals are weakly to moderately magnetic in all of the mineralogic varieties studied except in the *very fine grained hematite* variety in which these forms reacted moderately to strongly to the magnetized probe. This indicates that essentially all of the hematite, in its three forms, is somewhat magnetically susceptible and x-ray powder photographs have proven that the magnetic material is definitely hematite and not magnetite or maghemite.

Manganese oxide occurs primarily in the *quartz specularite-pyrolusite* variety but it also occurs in very minor amounts in the *quartz-granular hematite* and *quartz-specularite-granular hematite* types. Reactions to hydrogen peroxide, indicative of the presence of manganese, generally occurred in intergranular areas and along grain perimeters, indicating that manganese-bearing solutions migrated through these varieties after the formation of quartz grains. The manganese may have originally been psilomelane ($MnO.MnO_2 2H_2O$) or hausmannite (Mn_2O_4) and subsequently decomposed to pyrolusite and birnessite.

The pre-metamorphosed iron formation probably consisted of intermixed bands of chert, cherty ferric-ferrous iron oxides and magnetite. The silica and iron oxide were probably syntectonicaly recrystallized to quartz and specularite during metamorphism. The spatial relationships between quartz and specularite grains suggests the complete recrystallization of the quartz prior to the recrystallization of the hematite as specularite. The generally euhedral polygonal form of the quartz grains with straight grain boundaries and triple boundary junctions suggests that conditions favorable for good ionic mobility existed during recrystallization.

The original fine grained magnetite may have recrystallized into larger grains, but remained chemically unchanged at least during the early stages of metamorphism.

The presence of relict features suggestive of magnetite grains in zones of amorphous hematite in the quartz-granular hematite, quartz-specularite-granular hematite and one of the quartz-specularite-relict silicate samples leads the writer to believe that the magnetite was converted to martite either during the late stages of metamorphism or during the post metamorphic period. The indistinct grain boundaries in a few of the relict structures and individual martite grains in the amorphous hematite zones suggests that much of the hematite in the martite grains was later remobilized and redeposited practically in situ. The emplacement of amorphous hematite in fractures, and as a cement between individual grains of specularite and quartz must have occurred after recrystallization of the quartz and specularite.

The widespread association of martite and amorphous hematite in many of the specimens indicates that magnetite was formerly an appreciable constituent in certain stratigraphic horizons of the Julian deposit the same as it has been observed to be in the unoxidized and unleached deposits.

Additional microscopic evidence of post metamorphic leaching has been observed as; (1) the extremely friable nature of many of the ore specimens, (2) the presence of the relicts of leached silicate minerals, (3) vugs and cavities possibly representing former carbonate minerals, (4) limonitic stains on quartz and specularite grains, (5) coatings of limonite and soft red hematite in vugs, (6) micro-fractures filled with goethite, and soft red hematite, and (7) the quite widespread occurrence of manganese oxide or hydroxide in cavities and vugs in the specimens of the quartz specularite manganese oxide variety and in the intergranular areas of many specimens of the other varieties. The water necessary for the leaching solutions may have been of meteoric origin.

An additional aspect determined by this study is that the megascopic identification of mineralogic varieties is reliable in reference to the ferruginous quartzite, quartz-specularite-pyrolusite, quartz-specularite-relict silicate and fine grained hematite types. The quartz-specularite, quartz-specularite-granular hematite and quartz-granular hematite varieties however, are not as precisely determined by hand specimen examination alone.

Based on the parameters listed on page 59, several samples had to be reclassified. The quartz-specularite and quartz-specularite-granular hematite types required the most classification changes, resulting in a decrease from 35 to 20 samples of the former type and an increase from 25 to 35 of the latter type.

Magnetic Studies

This study shows that variations in ground magnetic responses are probably not attributable to appreciable amounts of magnetite in the ore. The magnetite-iron filings fractions of the samples tested exceeds 1% of the sample weight in only two instances, e.g. M-2A - 1.02%, and M-16 - 1.29%. In the remaining samples, this fraction ranges from a minimum of trace amounts to a maximum of 0.70% in sharp contrast with up to 30% magnetite reported in other deposits of metamorphosed oxide facies iron formation in the Wabush region, and it indicates that the ground magnetic responses recorded over the Julian deposit must be due to unusual magnetic characteristics of the hematite.

The magnetic susceptibility tests have demonstrated that there are definite differences in the degree of magnetic susceptibility exhibited by the ferruginous concentrates of selected samples. The magnetic susceptibility of these concentrates ranges from less than one fourth to over two times that of a concurrently tested standard sample containing 2% magnetite. The fact that concentrates of different samples exhibit different degrees of magnetism clearly indicates that the various magnetic responses obtained by a magnetometer are not an expression of the quartz-iron mineral ratio. This would probably be the case if the concentrates of all samples had exhibited approximately the same degree of magnetic susceptibility.

The susceptibility tests indicate that specularite from samples of the quartz-specularite and quartz-specularite-relict silicate varieties is considerably more magnetic than martite-amorphous hematite from the quartz-granular hematite ore type. The ratio value ranges obtained for the latter material represent the combined magnetic effects of both forms because there was not a convenient means of separating the martite and amorphous hematite fractions and testing them individually.

The range I and II ratio values obtained for concentrates of martite-amorphous hematite are probably representative of the normal magnetic susceptibility of hematite and are not likely to be due to the effect of the smaller average grain size of this material. The higher ratio values obtained for the specularite are probably due to variable degrees of ordering of the Fe ions in this form of hematite in the Julian deposit. The range II to range IV ratio values obtained for concentrates consisting of a mixture of specularite and martite-amorphous hematite from the quartz-specularite granular hematite variety only indicate the mixed composition of the concentrates, and the magnetic susceptibility cannot be related to the specularite: martite-amorphous hematite ratio on a sample to sample basis.

Although the ratio values obtained for sample concentrates and the outcrop ground magnetic values cannot be directly compared because of the respective volumetric differences in iron oxide content, a correlation appears to exist between the ratio value ranges of concentrates and the selected outcrop gamma values at the extremes of the respective scales. That is, the outcrops with the highest and lowest gamma values may be directly related to concentrates with the highest and lowest ratio value ranges. A direct relationship is indicated between outcrops with values of less than 5000γ and their sample concentrates which have ratio values in ranges I and II, and between outcrops with ground magnetic values above 8000γ and their concentrate ratio values which have ratio values in ranges IV through VIII. Correlations between outcrops with values of 5000γ to 7000γ and their sample concentrate ratio value ranges however, are only suggested.

A direct relationship between the volume percent specularite, the ratio value range of the concentrate and the outcrop gamma value is indicated for samples containing less than 22.5% specularite. These samples represent outcrops with ground magnetic values of less than 6000γ. Plots of the other samples are so randomly scattered in reference to these variables that the relationships are inconclusive.

This study has been undertaken with a limited number of samples, a susceptibility meter of non commercial manufacture and techniques heretofore untried; hence, some of the data is rather inconclusive. The writer believes, however, sufficient relationships have been indicated or suggested between the mineralogy, volume percent specularite, ratio value ranges, and outcrop gamma values of the Julian ore, so that further study involving a greater number of samples, an instrument designed for 'whole rock' magnetic susceptibility determinations, and more refined techniques is warranted.

Addenda

The following future projects should be undertaken to provide data allied to the present study;

1. A statistical study of the relationship between the sizes, shapes and intergrain boundaries of quartz and the iron minerals within samples of specific stratigraphic units of the ore body to determine if these factors have genetic significance.
2. A comparison of the magnetic susceptibilities of a number of whole rock samples, i.e., without separation of the magnetite, quartz and hematite fractions.
3. A separation of martite, specularite and amorphous hematite from the quartz-specularite-granular hematite samples and a comparison of the susceptibilities of these individual forms of hematite with those of concentrates of the same samples containing a combination of the three forms of hematite.

References Cited

American Geological Institute, 1962, Dictionary of Geological Terms, Garden City, New York, Doubleday and Company, p. 303.

American Society of Testing Materials, Joint Committee on Chemical Analysis by X-ray Diffraction Methods, X-Ray Diffraction Data Cards - Sixth Set - Philadelphia.

Bricker, O.P., 1965, Some Stability Relations In the System $Mn-O_2-H_2O$ at 25° and One Atmosphere Total Pressure, Am. Mineralogist, Vol. 50, p. 1296.

Bacon, L.O., 1957, Report on Magnetic Investigations Wabush Lake Deposit; Canadian Javelin Limited, company file, Ottawa, Ont.

Barret, W.M., 1947, A Semi Portable A.C. Susceptibility Meter, "Early Geophysical Papers", Society of Exploration Geophysicists, p. 17-24.

Canadian Javelin Limited, 1962, "The Julian Book", company file, Ottawa, Ont.

Dobrin, M.B., 1952, Introduction to Geophysical Prospecting: New York, McGraw-Hill, p. 103-155.

Fahrig, W.F., 1960, Shabogamo Lake, Newfoundland and Quebec, 23G E 1/2, Geol. Survey of Canada, Paper 60-9.

Gastil, G., Blais, R., Knowles, D.M. and Bergeron, R., 1960, The Labrador Geosyncline: Internat. Geol. Cong. 21st, Copehnagen 1960, pt. IX, Pre Cambrian Stratigraphy and Correlations, p. 21-38.

------, R.G. and Knowles, D.M., 1960, Geology of the Wabush Lake Area, Southwestern Labrador and Eastern Quebec: Geol. Soc. American Bull., v. 71., p. 1243-1254.

Gill, J.E., Bannerman, H.M. and Tollman, C., 1937, Wapussakatoo Mountains, Labrador: Geol. Soc. America Bull., v. 48, no. 5, p. 576-586.

Gross, G.A., 1960, Iron Formations of The Labrador Geosyncline: Geol. Survey of Canada, paper 60-30.

Harrison, J.M., 1952, Quebec-Labrador iron belt, Quebec and Newfoundland: Preliminary Report, Geol. Survey of Canada, paper 52-20.

Hess, H.H., 1959, Notes on Operation of Frantz Isodynamic Separator: Princeton University, Princeton, N.J.

Hoel, P.G., 1960, Elementary Statistics: New York, John Wiley & Sons, p. 242-244.

Howell, B.F., Jr., Introduction to Geophysics, New York, McGraw Hill, p. 342.

Jackson, G., 1962, The geology of the Neal (Virot) Lake Area, West of Wabush Lake, Labrador, with special reference to the Iron Deposits: Unpublished Ph.D. Thesis, McGill University, Montreal.

James, H.C., 1954, Sedimentary Facies of Iron Formation: Econ. Geology, v. 49, no. 3, p. 235-263.

Klein, C., 1960, Detailed Study of the Amphiboles and Associated Minerals in the Wabush Iron Formation Labrador; unpublished MSc. thesis, McGill University, Montreal.

Knowles, D.M., 1955, Geology and Petrology of the Wabush Lake Iron Formation: unpublished MSc. thesis, Michigan College of Mining and Technology, Houghton, Mich.

------------- 1967, The Structural Development of Labrador Trough Formations in the Grenville Province, Wabush Lake Area, Labrador: unpublished Ph.D. thesis, Columbia University, New York.

------------- 1968, Canadian Javelin Ltd., Ottawa, Ont., Personal Communication.

------------- and Gastil, R.G., 1959, Metamorphosed Iron Formation In Southwestern Labrador: Bull. Can. Inst. Mining and Metallurgy V. 62, p. 503-510.

Lindsley, D.H., Andreasen, G.E., and Balsey, J.R., 1966, Magnetic Properties of Rocks and Minerals: Geol. Soc. Am. Mem. 97; Handbook of Physical Constants - Revised Edition, Clark, S.P., editor, p. 543-552.

Low, A.P., 1895, Report on Explorations in the Labrador Peninsula, Along the East Main, Koksoak, Hamilton, Manicuagan and Portions of Other Rivers in 1892-93-94-95, Geol. Surv. of Can. Ann. Report, V. VIII.

Pickands Mather & Co., 1957, Report of Exploration Julian Ore Deposit: Canadian Javelin Ltd., company file, Ottawa, Ont.

Short, M.N., 1940, Microscopic Determination of The Ore Minerals: U.S. Geol. Survey Bull. 914, 314.

Stubbins, J.B., Blais, R.A. and Zajac, I.S., 1961, Origin of the Soft Iron Ores of the Knob Lake Range: Trans. Can. Inst. Min. and Met. VLXIV pp. 3752.

United States Geological Survey, 1958, Suggestions to Authors of The Reports of The United States Geological Survey: fifth edition, Washington, D.C., U.S. Gov't Printing Office, p. 105-121.

Weiss, Lionel, 1957, Canadian Javelin Limited Report: company file, Ottawa, Ont.

White, D.A., 1954, The Stratigraphy and Structure of the Mesabi Range, Minnesota: Minn. Geol. Survey Bull. 38, 92 p.

Wynne-Edwards, H.R., 1961, Ossokmanuan Lake, Newfoundland: Geol. Survey of Canada, Map 17 - 1961.

APPENDIX A

Sample Selection Procedure

The following procedure was utilized to select specific samples. All of the samples of each type were randomly laid out in a pattern as close as possible to that of a square. Frequently, however, an odd number of samples prohibited the formation of a perfect square. This procedure was followed to eliminate the possibility of having the samples grouped in the square according to their location on the ore body, which could happen because the samples were packed for shipment as they were collected each day, and as daily mapping was confined to particular areas, the orderly unpacking and spreading out of the samples might reflect specific locations.

Once the samples were laid out in a square, the table of random numbers (Hoel (1960) pg. 242-243) was utilized to make the final selection. The basic procedure followed was to let the first digit in an arbitrarily selected row in each group of five random numbers in a particular column represent a row number in the square of samples, and the second digit represent a column number in the same square of samples. A different combination of rows and columns in each group of five random numbers was used for each square. An example of the procedure followed is presented below.

* Random Numbers

I	II	III
13762	14378	55117
14195	93761	71321
41653	14982	86508
71029	23459	14916
84495	23459	14916
49862	31466	72915
13597	25801	14928
60143	64551	10661
91273	25390	77765
48712	55541	19423

---

* from Elementary Statistics: Hoel - 1960 pp. 242-243

For selection, use the first two digits in the third row in each group of five random numbers in columns I, II and III. These would be:

Digits	Refer to Square of samples	
	Column No.	Row No.
41	4	1
60	6	0
14	1	4
64	6	4
86	8	6
10	1	0

This procedure was followed until the required number of samples per ore type was obtained. In certain cases, the first two digits of the random number could not possibly refer to a square row/column number, and in this event, the next prescribed random number in the proper sequence was used.

Selection Procedure by Mineralogic Type

Quartz-Specularite

Number of Samples - 152

Number to mount - 35

Field (square of samples) 8 x 13 plus 4 x 12

Selection Procedure: Ref. Hoel - Elementary Statistics p. 242 Table III.

Select first two digits first row of each group of five random numbers in columns 1, 2, 3, 4, 5 and 6. Let first digit refer to row number and second digit refer to column number in field of samples.

With the exception of choosing the random numbers the same procedure was followed in selecting samples of all of the mineralogic varities.

TABLE OF SAMPLE NUMBERS, LOCATIONS AND CLASSIFICATIONS

Sample No.	Location	Mineralogic Type	Reclassified Mineralogic Type
1*	11310N 10975E	Qtz.-Spec.-Mn Oxide	Same
2	9080N 10825E	Qtz.-Spec.-Mn Oxide	Same
3	TR 14+55 20S	Qtz.-Spec.-Mn Oxide	Same
4	1180N 11210E	Qtz.-Spec.	Same
5*	8775N 10385E	Qtz.-Spec. Gran.	Same
6*	9745N 8660E	Qtz.-Spec.	Same
7	9175N 9745E	Qtz.-Gran.	Same
8	10190N 10950E	Qtz.-Spec.-Gran.	Same
9	8720N 10225E	Qtz.-Spec.-Gran.	Same
10	10650N 11015E	Qtz.-Spec.-Gran.	Qtz.-Gran.
11	TR 13+30 50N	Qtz.-Spec.-Gran.	Qtz.-Spec.
12*	TR 7 + 15 30N	Qtz.-Spec.-Gran.	Same
13	11150N 11175E	Qtz.-Spec.-Gran.	Qtz.-Spec.

Sample No.	Location	Mineralogic Type	Reclassified Mineralogic Type
14*	11150N 10975-11000E	Qtz.-Spec.	Same
15	10650N 10165E	Fe Qte.	Qtz.-Spec.-Gran.
16	10350N 10925E	V.f.g. Hem.	Same
17	10515N 10725E	Fe Qte.	Qtz.-Gran.
18	9880N 10455E	Fe Qte.	Same
19	9390N 10810E	Qtz.-Gran.	Same
20	11360N 10860E	Qtz.-Gran.	Same
21*	9880N 10930E	Qtz.-Gran.	Same
22	10155N 10285E	V.f.g. Hem.	Same
23	10545N 10560E	Qtz.-Spec.-Gran.	Same
24	11045N 10455E	Qtz.-Spec.-Gran.	Qtz.-Gran.
25*	8565N 9700E	Qtz.-Gran.	Qtz.-Spec.-Gran.
26	10800N 10285E	Fe Qte.	Qtz.-Gran.
27	11520N 10660E	Qtz.-Spec.	Same

Sample No.	Location	Mineralogic Type	Reclassified Mineralogic Type
28	11020N 11100E	Fe Qte.	Same
29*	8695N 8320E	Qtz.-Spec.	Qtz.-Gran.
30	9600N 10340E	Qtz.-Gran.	Same
31	8810N 9900E	Qtz.-Spec.-Gran.	Same
32	10900N 11050E	Qtz.-Spec.-Gran.	Same
33	9825N 10900E	Qtz.-Spec.	Same
34*	8675N 9025E	Qtz.-Spec.	Qtz.-Gran.
35	10850N 10980E	Qtz.-Spec.-Gran.	Qtz.-Gran.
36	11170N 10600E	Qtz.-Spec.	Qtz.-Spec.-Gran.
37	10430N 10700E	Qtz.-Spec.	Qtz.-Gran.
38*	9255N 9375E	Qtz.-Spec.	Qtz.-Spec.-Gran.
39	8770N 8800E	Qtz.-Spec.	Qtz.-Spec.-Gran.
40*	11090N 11040E	Qtz.-Spec.	Qtz.-Spec.-Gran.
41	TR 6+50 75N	Fe Qte.	Same

Sample No.	Location	Mineralogic Type	Reclassified Mineralogic Type
42	8850N 10750E	Qtz.-Spec.	Same
43	8550N 9220E	Qtz.-Spec.	Same
44	8770N 9100 - 9120E	Qtz.-Spec.	Qtz.-Spec.-Gran.
45	9420N 10750E	Qtz.-Spec.	Same
46	8635N 9250E	Qtz.-Spec.	Same
47	10620N 10650E	Qtz.-Spec.	Same
48*	10720N 11050E	Qtz.-Spec.	Same
49	8640N 9390E	Qtz.-Spec.	Same
50	10900N 10825E	Qtz.-Spec.	Same
51	9070N 8705E	V.f.g. Hem.	Same
52	10690N 11035E	Qtz.-Spec.	Qtz.-Spec.-Gran.
53	8660N 9215E	Qtz.-Spec.	Qtz.-Spec.-Gran.
54	10170N 8250F	Qtz.-Spec.-Gran.	Qtz.-Spec.
55	8600N 9550E	Qtz.-Spec.-Gran.	Fe Ozite

Sample No.	Location	Mineralogic Type	Reclassified Mineralogic Type
56	TR 13408 10S	Qtz.-Gran.]	Same
57	11350N 10925E	Qtz.-Gran.	Same
58*	9815N 8580E	Qtz.-Spec.	Same
59	11425N 10750E	Qtz.-Spec.-Gran.	Fe Qte.
60	9015N 10815E	Qtz.-Spec.-Gran.	Same
61*	9555N 8690E	Qtz.-Gran.	Same
62	TR 16 + 12 30S	Qtz.-Spec.	Qtz.-Spec.-Gran.
63*	10105N 10990E	Qtz.-Gran.	Same
64	TR 3 + 75 C L	Qtz.-Spec.-Gran.	Same
65	11415 - 430N 10820E	V.f.g. Hem.	Same
66	TR 16 + 12 30S 10000/9740E	Qtz.-Spec.-Gran.	Same
67	10455N 10530E	Fe Qte.	Qtz.-Gran.
68	9115N 9700E	Qtz.-Spec.-Gran.	Qtz.-Gran.
69	TR 18+75 - 19+00 8N	Qtz.-Spec.	Same

Sample No.	Location	Mineralogic Type	Reclassified Mineralogic Type
70	10200N 8310E	Qtz.-Spec.	Qtz.-Spec.-Gran.
71	10140N 11100E	Qtz.-Spec.-Gran.	Same
72	10500-520N 10750-770E	V.f.g. Hem.	Qtz.-Spec.
73*	8615N 8745E	Qtz.-Spec.	Same
74	9575N 8100E	Qtz.-Spec.-Gran.	Qtz.-Gran.
75*	11110N 11060E	Qtz.-Spec.	Qtz.-Spec.-Gran.
76	TR 11+65 C L	Qtz.-Gran.	Same
77*	9700N 8090E	Qtz.-Spec.-Gran.	Same
78	10500N 10600E	Fe Qte.	Same
79	8990N 9655E	Qtz.-Spec.	Qtz.-Spec.-Gran.
80*	11430N 10825E	V.f.g. Hem.	Same
81	TR 11+80 20N	V.f.g. Hem.	Qtz.-Gran.
82	10080N 10950E	Qtz.-Spec.	Qtz.-Spec.-Gran.
83*	10900N 10985E	Qtz.-Gran.	Qtz.-Spec.-Gran.

Sample No.	Location	Mineralogic Type	Reclassified Mineralogic Type
84	TR 13+40 8N	Fe Qte.	Qtz.-Spec.-Gran.
85	10165N 10950E	Qtz.-Spec.	Qtz.-Spec.-Gran.
86	10755N 10750E	Qtz.-Spec.-Gran.	Same
87	8745N 9565E	Fe Qte.	Qtz.-Gran.
88	10900N 10985E	Qtz.-Spec.	Qtz.-Spec.-Gran.
89	8470N 9700E	Qtz.-Gran.	Same
90	10800N 10285E	Qtz.-Spec.-Gran.	Fe Qte.
91	9225N 9205E	Qtz.-Spec.	Qtz.-Spec.-Gran.
92*	9895N 9500E	V.f.g. Hem.	Same
93	9820N 11175E	V.f.g. Hem.	Same
94	8715N 9500E	Qtz.-Spec.-Gran.	Qtz.-Gran.
95*	11100N 11215E	Qtz.-Spec.-Relict Silicate	Same
96	8550N 9875E	Qtz.-Spec.-Relict Silicate	Same

Sample No.	Location	Mineralogic Type	Reclassified Mineralogic Type
97*	TR 21+00 21+50 / C.L.	Qtz.-Spec.-Relict Silicate	Same
98	TR 20+40 / 20S	Qtz.-Spec.-Relict Silicate	Same
99	10860N	Qtz.-Spec.	Qtz.-Spec.-Gran.
100*	9080 - 9090N / 10750E	Qtz.-Spec.-Mn Oxide	Same

All sample numbers are presented on Geologic Map Fig. and plate #1.

---

* Denotes sample tested in magnetic susceptibility meter is reclassified sample.

APPENDIX B

Preparation of Polished Sections

The selected specimens were in bags bearing the proper grid co-ordinate numbers. Frequently, these bags contained from two to six small hand specimens, hence individual judgment was exercised in selecting the one sample from several which would be representative of all of those in the bag. Once the selection was made, the specimen was broken down to an approximately .5 - 1.0 inch cube with a screw type rock splitter. The initial flat surface was prepared at right angles to the mineral foliation by grinding the specimen on a wet, coarse lapidary wheel, and the samples were placed flat side down in cupcake or muffin tins which had been "greased" with Bio-Plastic Lubricant.

Wards *Bio-Plastic was used as the mounting agent. This material was prepared according to the supplier's instructions for mounting dry-opaque objects. The procedure followed was to mix 30 milliliters of the Bio Plastic with 56 drops of catalyst from an eyedropper, which would provide sufficient liquid to cover three or four specimens. If more than 30 ml. of Bio-Plastic was mixed at one time it would

---

* Ward's Natural Science Establishment, Rochester, New York

start to "set" before additional mounts could be prepared. Prior to covering each sample with Bio-Plastic, a 1/2" x 3/4" slip of paper bearing the sample co-ordinate numbers and mineralogic type was placed on top of the specimen. Once the mount was prepared, it was permanently identified by a durable, water-proof label.

Many of the quartz-specularite, quartz-specularite granular hematite and quartz-specularite-relict silicate samples were extremely friable, and normal sample mounting procedure would not suffice, because grains would "pluck out" when the sample was ground and polished. To overcome this problem, the friable specimens were impregnated with a weak solution of Bio-Plastic, mixed approximately as follows: thirty milliliters of Bio-Plastic were thinned with ten drops of methyl alcohol and mixed with thirty-five drops of catalyst. The samples were placed flat side down in the muffin tins containing approximately five milliliters of the thinned Bio-Plastic. Capillary action drew the solution into the sample where it hardened in about eight hours. The remaining portion of the sample could then be covered with normally prepared Bio-Plastic and allowed to stand 8 - 10 hours (over night). After hardening over night the mounted specimens were removed from the muffin tins and placed in a drying oven at 120° - 140°F, for two hours of curing.

The polishing procedure followed was simple but extremely time consuming. After considerable experimentation it was determined that the following method was the most efficient.

1. Flattening of the beveled edge of the mount on a #100 aluminum oxide wet vertical belt grinder to allow the specimen to be held firmly tangent to the belt.
2. Successive grinding with grit numbers 100, 250, and 500 on the wet aluminum oxide vertical belt grinder.
3. Dry polishing on a Buehler polishing disc with grinding paper grades 1, o, ol, and 02.
4. Final polishing on a Buehler Lapidary wheel with cerium oxide followed by chrome oxide.

The above procedure was sufficient to provide a highly polished surface on 95 of the samples. The manganese-bearing specimens and one of the quartz granular hematite samples were difficult to bring to a high lustre.

APPENDIX C.

SELECTED POLISHED SECTION DATA SHEETS

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE S.G.*

SHEET NO. 24

STUDENT: W. Blakeman COURSE Thesis DATE 3 April 67

NATURE OF ORE Meta Iron Fm. LOCATION SPEC. NO. 24

ORIENTATION 90° to Fol. REFERENCES:

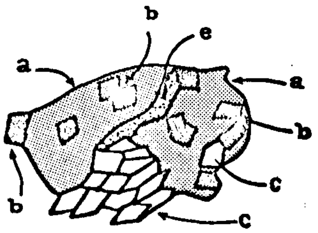
NATURE OF MINERALIZATION: MASSIVE (X), BANDED ( ), DISSEMINATED (X).

AVERAGE GRAIN SIZE:	ORE MINERALS	GANGUE
	Martite .36-.50mm	Qtz .18-.36mm long dim.
	Relict (Mag) Strs. .12-.18mm	

SKETCH OR PHOTO:

MAGNIFICATION 20 X

REMARKS:



KEY:
a. Amorphous Hem.
b. Martite
c. Quartz
d. Soft red Hem.
e. Cavity
f.
g.
h.

MINERALS PRESENT
BY 500 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Mart. & Amor.	295	59.0	6. Qtz.	194	39.8
2. Soft Red	10	2.0	7.		
3. Spec.	Tr.	Tr.	8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Specimen is essentially bi mineralic. Qtz. & mart-amorph. Minor red hem. in fractures and 2-5 grains of spec. noted. Martite grains have form of mag. crystals. Amorph. hem. is about 55% of Fe_2O_3. Qtz. grains are euhedral - sub angular - sub rounded. Many areas show martite completely surrounding an isolated qtz. grain. Moderate reaction to H_2O_2 in voids and perimeters of amorph. masses adjacent to voids. Martite and amorph. hem. powder are very magnetic.

CLASSIFICATION
RECLASSIFIED - Gran.

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE S.G.

SHEET NO. 32

STUDENT: W. Blakeman COURSE Thesis DATE 18 April 67

NATURE OF ORE Meta Iron Fm. LOCATION SPEC. NO. 32

ORIENTATION 90° to Fol. REFERENCES:

NATURE OF MINERALIZATION: MASSIVE ( ), BANDED (X), DISSEMINATED ( ).

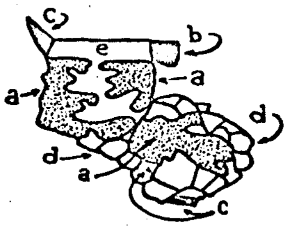
AVERAGE GRAIN SIZE: ORE MINERALS Spec .09-.24mm
Mart .1-.2mm
Amorph .2-.5mm

GANGUE
Qtz .18-.36
Cavities .18-.36
(carbonate?)

SKETCH OR PHOTO:

MAGNIFICATION 20 X

REMARKS:



KEY:
a. *Amorphous hem.*
b. *Martite*
c. *Spec.*
d. *Quartz grain*
e. *Secondary Quartz*
f.
g.
h.

MINERALS PRESENT
BY 500 POINT COUNT

	ORE	COUNT	%		GANGUE	COUNT	%
1.	Amorphous hem	90	18	6.	Quartz	305	61
2.	Spec	17	3.4	7.	Cavities	88	17.6
3.				8.			
4.				9.			
5.				10.			

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Essentially qtz and amorphous hem with about 20% of Fe_2O_3 as recognizable martite, minor spec. Qtz. and amorphous hem. grains are commonly intergrown. Possible secondary quartz fills fractures in zones of amorphous hem. Qtz commonly contains opaque inclusions up to .1 mm in size. Entire specimen is very friable and contains about 20% cavities (former carbonate) about .2-.3mm in length. Cavities now filled with bio plastic. Hem powder is moderately magnetic. Reaction to H_2O_2 along grain boundaries & surface is moderate.

CLASSIFICATION Spec gran. (lean)

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE Spec.

SHEET NO. 38

STUDENT: W. Blakeman COURSE Thesis DATE 25 April 67

NATURE OF ORE Meta Iron Fm. LOCATION SPEC. NO. 38

ORIENTATION 90° to Fol. REFERENCES:

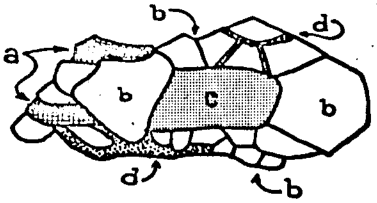
NATURE OF MINERALIZATION: MASSIVE (x) and BANDED (x), DISSEMINATED ( ).

AVERAGE GRAIN SIZE:	ORE MINERALS	GANGUE
	Spec. .09x.2-.4mm	Quartz .09-.18mm
	Amorph. hem. .36-.72	

SKETCH OR PHOTO:

MAGNIFICATION 25 X

REMARKS:



KEY:

a. Spec.
b. Quartz
c. Martite
d. Amorphous hem. Cement
e.
f.
g.
h.

MINERALS PRESENT
BY 508 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Spec.	97	19.9	6. Quartz	346	69.3
2. Martite & Amorph.	65	10.8	7.		
3.			8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Sample is primarily quartz and euhedral tabular spec. Some of the spec is deformed around qtz. grains. A few large non crystalline areas of amorphous hematite noted, WHICH HAVE SUGGESTED RELICT MAG STRUCTURES. Long axes of quartz and spec grains are parallel to each other in most cases. Quartz grains are very angular but have sharp clean boundaries. Amorphous hematite commonly forms a cement between quartz grains. Spec powder and mart powder are very magnetic. Reaction to H_2O_2 is weak and only along spec and martite grain boundaries.

RECLASSIFIED
CLASSIFICATION Spec Gran.

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE Spec.

SHEET NO. 39

STUDENT: W. Blakeman COURSE Thesis DATE 2 May 67

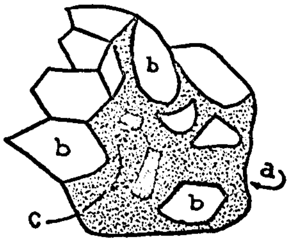
NATURE OF ORE Meta.Iron Fm. LOCATION SPEC. NO. 39

ORIENTATION 90° to Fol. REFERENCES:

NATURE OF MINERALIZATION: MASSIVE ( ), BANDED (X), DISSEMINATED ( ).

AVERAGE GRAIN SIZE:	ORE MINERALS	GANGUE
	Spec. .09x.36mm	Quartx .2mm
	Amorph. up to 5.0mm	

SKETCH OR PHOTO:
MAGNIFICATION 60 X
REMARKS:



KEY:
a. *Amorphous hem.*
b. *Quartz*
c. *Spec.*
d.
e.
f.
g.
h.

MINERALS PRESENT
BY 507 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Spec.	133	26	6. Quartz	344	69
2. Amorph	26	5	7.		
3. Limonite	4	Tr.	8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Essentially quartz and spec with minor amorphous hematite and limonite. Amorphous hem. commonly forms a cement and fills fractures in quartz grains - see sketch. Very minor amount of relict (mag?) features noted. A few quartz grains have minute inclusions -, Spec powder is moderately magnetic - Reaction to H_2O_2 very weak along spec. grain boundaries and in cavities between grains. Spec. grains are euhedral - tabular quartz grains are generally euhedral - angular and with sharp boundaries.

CLASSIFICATION Spec. Gran.

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY CODE Qtz-Spec

SHEET NO. 12

STUDENT: W. Blakeman COURSE Thesis DATE 3 May 67

NATURE OF ORE Meta. Iron Fm. LOCATION ______ SPEC. NO. ______

ORIENTATION 90° to Fol. REFERENCES: ______

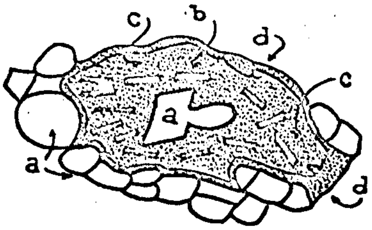
NATURE OF MINERALIZATION: MASSIVE (X), BANDED (X), DISSEMINATED ( )

AVERAGE GRAIN SIZE:	ORE MINERALS	GANGUE
	Specularite .1x.3-.5mm	Quartz .2-.4mm
	Martite .2-.4mm	Jasper - Amorph
	Amorphous hem N/A	

SKETCH OR PHOTO:

MAGNIFICATION 20 X

REMARKS:



KEY:

a. Quartz
b. Specularite
c. Jasper
d. Amorphous hem.
e. Martite - none
f. shown here
g. ______
h. ______

MINERALS PRESENT

BY _____ POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Specularite	260	49.4	6. Quartz	232	44
2. Martite	4	Tr.	7. Jasper	21	3.9
3. Amorph. hem	6	Tr.	8.		
4. Limonite (B)	9	2.0	9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Predominantly quartz and specularite with very minor martite, amorphous hematite and limonite. Areas between quartz grains frequently stained by limonite. Jasper appears to be altering to hematite in minor areas. Amorphous hematite frequently fills areas between quartz grains. In banded areas quartz and specularite grains are discrete and euhedral. In massive zones, quartz and specularite grains are intergrown. Reaction to H_2O_2 - neg. Specularite and amorphous hematite are very weakly magnetic.

CLASSIFICATION Quartz-specularite

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE S.C.

SHEET NO. 60

STUDENT: W. Blakeman COURSE Thesis DATE 3 Oct. 67

NATURE OF ORE Meta Iron Fm. LOCATION ______ SPEC. NO. 60

ORIENTATION 90° to Fol. REFERENCES: ______

NATURE OF MINERALIZATION: MASSIVE ( ), BANDED (X), DISSEMINATED ( ).

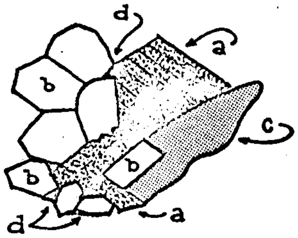
AVERAGE GRAIN SIZE:	ORE MINERALS	GANGUE
	Amorph .4-.7mm masses	Quartz .2-.3 mm
	Spec .1x.3-.5 mm	

SKETCH OR PHOTO:

MAGNIFICATION 40 X

REMARKS:

Martite crystal



KEY:

a. *Spec.*
b. *Quartz*
c. *Amorphous hem.*
d. *Limonite*
e.
f.
g.
h.

MINERALS PRESENT
BY 507 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Amorphous hem	86	17.2	6. Quartz	357	71
2. Spec	64	12.8	7.		
3. Limonite	Tr.	Tr.	8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Quartz and spec with amorphous hematite in irregular forms. Spec Spec is euhedral, tabular, generally all grains of spec are parallel, but some are at large see sketch. Quartz is generally euhedral with clean straight boundaries. Spec and amorphous hem powder are weakly magnetic. Negative reaction to H_2O_2. Note sketch of martite former magnetite crystal observed in this section.

CLASSIFICATION Spec gran.

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE FeQte*

SHEET NO. 67

STUDENT: W. Blakeman COURSE Thesis DATE 4 Oct. 67

NATURE OF ORE Meta. Iron Fm. LOCATION ______ SPEC. NO. 67

ORIENTATION 90° to Fol. REFERENCES: ______

NATURE OF MINERALIZATION: MASSIVE ( ), BANDED (x), DISSEMINATED ( ).

AVERAGE GRAIN SIZE: ORE MINERALS ______ GANGUE ______

Amorphous hem - massive zones Qtz .2-.3mm

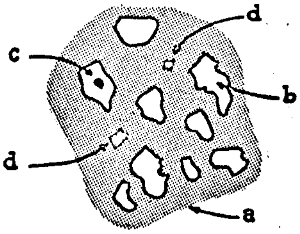
Spec .1x.3mm

Martite

SKETCH OR PHOTO:

MAGNIFICATION 40 x

REMARKS:



KEY:

a. Amorphous hem.
b. Quartz
c. Opaque Inclusion
d. Probable martite
e. Grain
f.
g.
h.

MINERALS PRESENT

BY 500 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Amorph & Mart	221	44.2	6. Qtz	277	55.4
2. Spec	2	Tr.	7.		
3.			8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features).

Essentially massive amorphous hem. & qtz. Only a few martite grains noted and these have indistinct boundaries. Total amorph is greater than 90% of Fe_2O_3. Present qtz grains are anhedral & very angular, irregular surfaces intergrown with amorph. Amorph appears to be solid matrix. At 400X, fractures in qtz observed to carry amorph. No preferred orientation noted. Minor inclusions noted in a few qtz grains. Amorph-powder is weakly magnetic. Weak reaction to H_2O_2 along grain boundaries - neg reaction on polished (solid) surfaces.

RECLASSIFIED Gran.
CLASSIFICATION ______

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE Qtz-Spec

SHEET NO. 69

STUDENT: W. Blakeman COURSE Thesis DATE 5 Oct. 67

NATURE OF ORE Meta. Iron Fm LOCATION ____ SPEC. NO. 69

ORIENTATION 90° to Fol. REFERENCES: ____

NATURE OF MINERALIZATION: MASSIVE ( ), BANDED (X), DISSEMINATED ( ).

AVERAGE GRAIN SIZE: ORE MINERALS ____ GANGUE ____

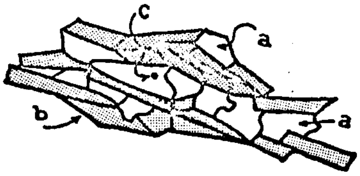
Specularite .1-.2x.4-.6mm

Quartz-.1-.2mm

SKETCH OR PHOTO:

MAGNIFICATION 30 X

REMARKS:



KEY:

a. Quartz
b. Specularite
c. Martite(?) Inclusion
d.
e.
f.
g.
h.

MINERALS PRESENT
BY 500 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Spec	206	41.2	6. Quartz	294	58.8
2.			7.		
3.			8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Bi mineralic, quartz and euhedral tabular specularite. Quartz grains are anhedral - sub rounded and long axes parallel long axes of spec. grains, qtz-qtz-grain boundaries are interlocking and qtz-spec. grain boundaries are sharp straight lines. Fractures in spec are filled with secondary quartz or amorphous hem (very minor). Powdered spec. is very magnetic. Reaction to H_2O_2 is moderate along quartz grain boundaries. A few martite (?) inclusions noted in qtz grains.

CLASSIFICATION Quartz-specularite

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE *Spec.

SHEET NO. 70

STUDENT: W. Blakeman COURSE Thesis DATE 5 Oct. 67

NATURE OF ORE Meta. Iron Fm. LOCATION SPEC. NO. 70

ORIENTATION 90° to Fol. REFERENCES:

NATURE OF MINERALIZATION: MASSIVE (x), BANDED ( ), DISSEMINATED ( ).

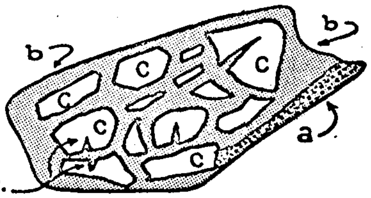
AVERAGE GRAIN SIZE: ORE MINERALS GANGUE

Spec. .2x.4 .3mm.

SKETCH OR PHOTO:

MAGNIFICATION 35 X

REMARKS:



Note fractures filled with amorphous hem.

KEY:

a. Spec.
b. Amorphous hem.
c. Quartz
d.
e.
f.
g.
h.

MINERALS PRESENT

BY 500 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Amorph & Mart	290	58	6. Quartz	165	33
2. Spec.	45	9	7.		
3.			8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Essentially quartz-amorphous hematite and spec. A few individual martite grains observed, but they constitute less than 10% of "granular" i.e. non spec hematite. Quartz grains generally anhedral, sub rounded to sub angular - often fractured and cemented by amorphous hem. No pronounced preferred grain orientations. Amorphous hematite and spec. are moderately magnetic. Reaction of Fe minerals to H_2O_2 is neg. to very weak.

*CLASSIFICATION Spec. Gran.
*RECLASSIFIED

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE Vfg Hem.

SHEET NO. 80

STUDENT: W. Blakeman COURSE Thesis DATE 10 Oct. 67

NATURE OF ORE Meta. Iron Fm. LOCATION SPEC. NO. 80

ORIENTATION 90° to Fol. REFERENCES:

NATURE OF MINERALIZATION: MASSIVE ( ), BANDED (X), DISSEMINATED (X).

AVERAGE GRAIN SIZE:

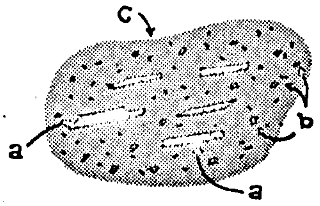
ORE MINERALS
Spec. 1 x .5 - .7mm
Opaque inclusions in Qtz .005 - .01 mm

GANGUE
Qtz - amorphous

SKETCH OR PHOTO:

MAGNIFICATION 20 X

REMARKS:



KEY:
a. Spec.
b. Opaque Inclusions
c. Quartz - Chert.
d.
e.
f.
g.
h.

MINERALS PRESENT
BY 500 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Spec	133	26.6	6. Qtz-chert	259	51.8
2. Inclusions	108	21.6	7.		
3.			8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Essentially qtz-spec and extremely fine grained inclusions, can't be definitely identified as spec - may be martite. Qtz is in form of chert, grain boundaries can't be distinguished, even under 400 power. Spec grains are euhedral, bladed & tabular, with definitely parallel orientation. Chert appears to be 'shot through' with the fine sized grains. These grains appear to be zones parallel to the long axes of spec grains. Boundaries between spec & chert are sharp, non intergrown. Spec powder is very magnetic. Reaction to H_2O_2 is neg - very weak along spec grain boundaries - neg elsewhere.

CLASSIFICATION Very fine grained hem.

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE Vfg Hem

SHEET NO. 92

STUDENT: W. Blakeman COURSE Thesis DATE 16 Oct. 67

NATURE OF ORE Meta. Iron Fm. LOCATION ______ SPEC. NO. 92

ORIENTATION 90° to Fol. REFERENCES: ______

NATURE OF MINERALIZATION: MASSIVE ( ), BANDED ( ), DISSEMINATED (X).

AVERAGE GRAIN SIZE: ORE MINERALS ______ GANGUE ______

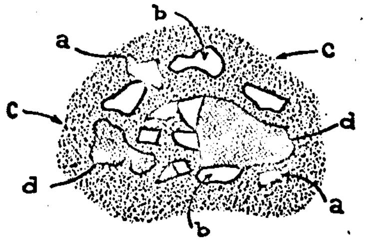
Martite (40%) .2-.4mm — Qtz .2-.3mm L dim

Amorphous hem (60%) irregular sizes

SKETCH OR PHOTO:

MAGNIFICATION 35 X

REMARKS:



KEY:

a. Martite
b. Quartz
c. Limonite
d. Amorphous hem.
e. ______
f. ______
g. ______
h. ______

MINERALS PRESENT
BY 510 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Mart			6. Quartz	211	41.4
2. Amorphous	169	33.1	7.		
3. Limonite	130	25.5	8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Iron minerals = martite, limonite & amorphous hem. Limonite may be secondary, and forms a matrix around martite and qtz grains as well as small masses of amorphous hem. Qtz grains are anhedral, angular, frequently fractured. Fractures commonly filled with amorphous hem or limonite. Fractures in martite & amorphous hem commonly contain limonite. Orientation of all grains appears to be completely random. Gran powder - non magnetic limonite powder - non to very weakly magnetic. Reaction to H_2O_2 - neg. to very weak on martite grain boundaries & in limonite areas.

CLASSIFICATION Limonitic granular hem.

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY CODE S.G.

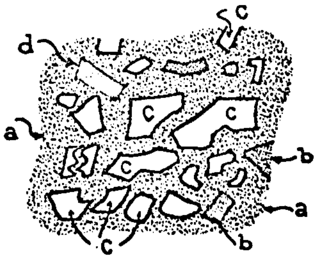
SHEET NO. 94

STUDENT: W. Blakeman COURSE Thesis DATE 17 Oct. 67
NATURE OF ORE Meta. Iron Fm. LOCATION SPEC. NO. 94
ORIENTATION ? REFERENCES:

NATURE OF MINERALIZATION: MASSIVE (X), BANDED ( ), DISSEMINATED ( ).

AVERAGE GRAIN SIZE:	ORE MINERALS Amorph. (70%)	GANGUE
	Martite .2-.4mm (30%)	Qtz .2-.5mm
	Spec .1-.2x.3-.5mm	

SKETCH OR PHOTO:
MAGNIFICATION 30 X
REMARKS:



KEY:
a. *Amorphous hem.*
b. *Martite*
c. *Quartz*
d. *Spec.*
e.
f.
g.
h.

MINERALS PRESENT
BY 500 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Amorphous&Mart	216	43.2	6. Quartz	270	54
2. Spec	14	2.8	7.		
3. Soft red hem	Tr.	Tr.	8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION
(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Predominantly amorphous hem & qtz with minor spec. Mart in recognizable grains makes up about 30% of total Fe_2O_3. Qtz grains commonly appear to be shattered & filled (fractures) with amorph or in a few cases - soft red hem. Qtz grains generally anhedral angular - but minor areas (bands) of euhedral qtz grains with smooth-straight intergrain boundaries noted. Only preferred orientation is that shown by a few spec grains. Martite grains often show relict (mag?) structure. Amorph hem serves as a cement in shattered qtz grain areas. Powdered hem is weakly to moderately magnetic - reaction to H_2O_2 - weak to moderate along martite grain boundaries & on their surfaces.

CLASSIFICATION Spec gran.

UNIVERSITY OF VERMONT
GEOLOGY DEPT.

ORE MICROSCOPY

CODE Mn

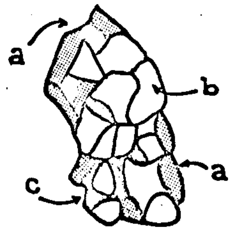
SHEET NO. 100

STUDENT: W. Blakeman COURSE Thesis DATE 18 Oct. 67
NATURE OF ORE Meta. Iron Fm. LOCATION ______ SPEC. NO. 100
ORIENTATION 90° to Fol. REFERENCES: ______

NATURE OF MINERALIZATION: MASSIVE ( ), BANDED (X), DISSEMINATED ( ).

AVERAGE GRAIN SIZE: ORE MINERALS ______ GANGUE ______
Specularite .1-.2 x .3-.7mm Quartz .2-.4mm
Cavities (MnO_2) .2-1.0 mm

SKETCH OR PHOTO:
MAGNIFICATION 25 X
REMARKS:



KEY:
a. Specularite
b. Quartz
c. Pyrolusite area
d.
e.
f.
g.
h.

MINERALS PRESENT
BY 500 POINT COUNT

ORE	COUNT	%	GANGUE	COUNT	%
1. Specularite	134	26.8	6. Quartz	282	56.4
2. Martite	11	2.0	7. MnO_2 Areas	74	14.8
3.			8.		
4.			9.		
5.			10.		

TEXTURAL INFORMATION

(Overall fabric, fabric of subunits, geometry of crystals, contacts, inclusions, replacements, relicts, fractures, micro breccias, anomalous features)

Sample allowed to soak in H_2O_2 for 1 min. to accentuate MnO_2 areas. Violent reaction to H_2O_2 along qtz & spec grain boundaries and irregularly shaped MnO_2 areas between grains. There are no hard MnO_2 minerals present, just sooty black powder. Spec is euhedral-tabular, with a general preferred orientation. Qtz grains are anhedral angular and often fragmented, generally w/o preferred orientation. Intergranular and fragmented areas filled with MnO_2 powder. Very minor amounts of MnO_2 noted. Spec powder is moderately magnetic.

CLASSIFICATION Quartz-specularite-pyrolusite.

APPENDIX D

Operating Instructions for Magnetic Susceptibility Meter

The following instruction will provide for the proper operation of this instrument. This will require a number of runs to familiarize the user with its capabilities and limitations.

I Preliminary Set-up

1.1 Locate instrument on bench away from electrical equipment which might produce magnetic fields which would affect readings and the sensitivity of this unit.

1.2 Connect to 115 volt AC power receptable, turn on and allow warm-up of fifteen minutes before balancing out the bridge circuit.

1.3 Without any samples inserted in receiving slot, balance the bridge to "zero" by adjusting the ten turn potentiometer. Adjust electrically and mechanically as close to zero as possible. Movement of instrument in a circular motion toward or away from the transformer tends to move pointer of meter either upward or downward. Try combination of movement of equipment mechanical and electrical balancing.

1.4 This effectively performs a nulling of the bridge. Generally the better the null the greater the sensitivity acquired for this type of detection. Null should be as close to zero as possible, but effective null is obtained at one scale division on millivolt meter.

II Operation

2.1 Once satisfactory results are obtained in the proper nulling of bridge, place known reference material within the slot provided for receiving test samples. Note reading.

2.2 Insert "unknown" sample and note reading. Frequently recheck equipment for proper nulls, reference samples, and etc., to assure repetative readings.

2.3 It is not anticipated that the unit will require further mechanical adjustment, but if nulls begin to rise higher over a long period of time, refer to paragraph 2.4.

2.4 Located on the end of the instrument opposite the sample receiving slot you will note a similar coil which is not provided with access for samples.

2.4.1 Loosen screws of field poles just enough to allow adjustment but not enough to allow slippage.

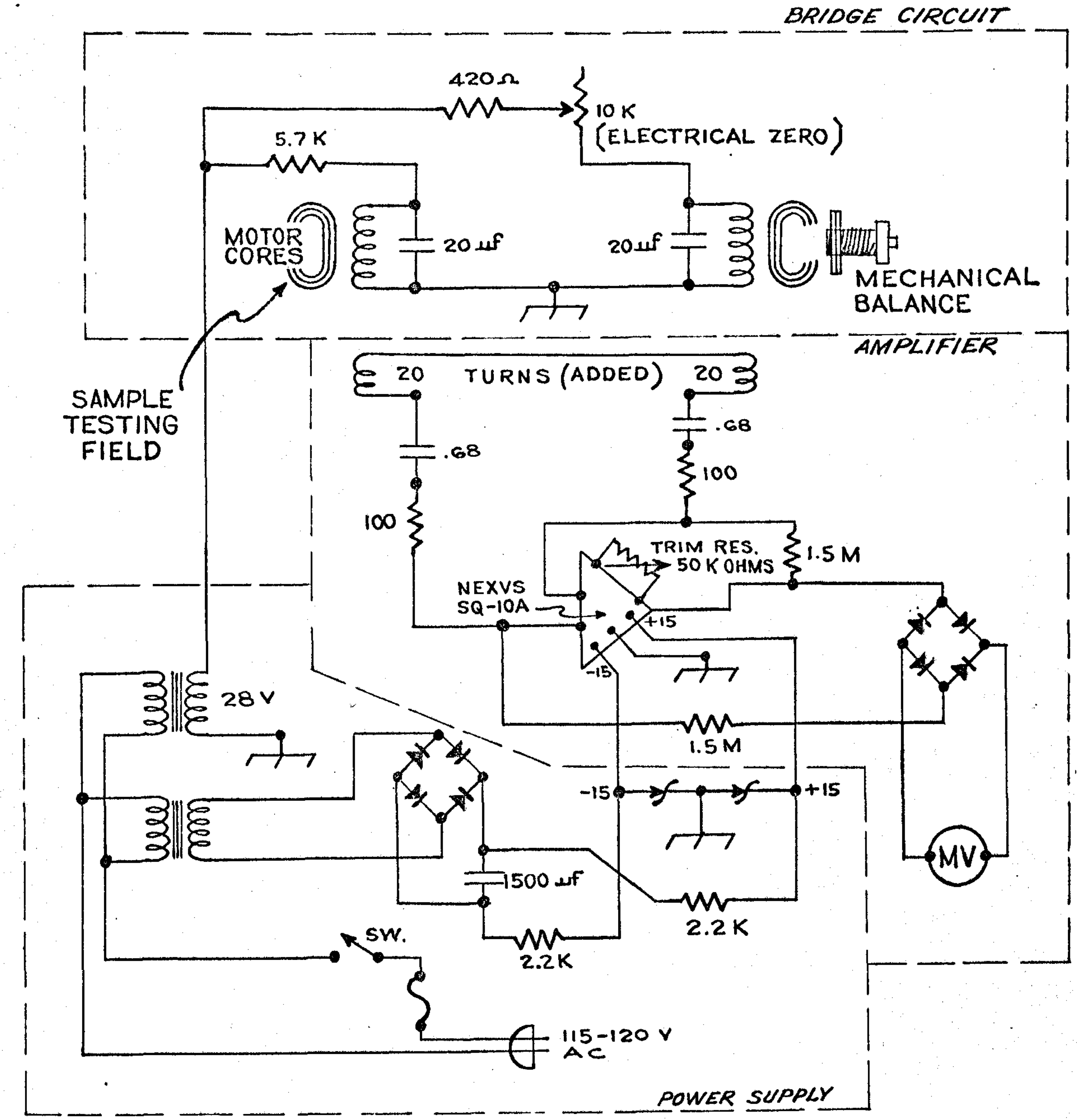
2.4.2 Slight movement of field poles and a combination of adjustment of potentiometer should reduce bridge to zero.

2.4.3 The nulling of the bridge in this manner requires repeated trials and patience.

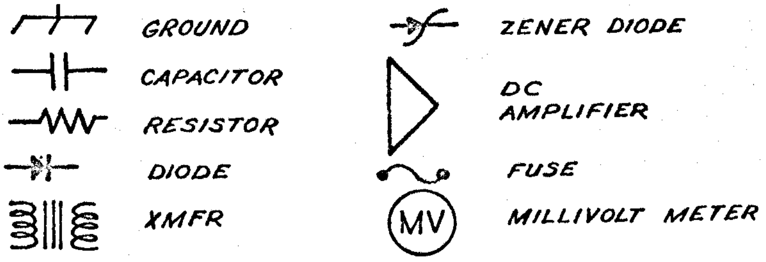
H. A. Preston
University of Vermont
Instrumentation and
Model Facility

13 December, 1967.

CIRCUIT DIAGRAM
FOR
MAGNETIC SUSCEPTIBILITY METER



SYMBOLS



UNIVERSITY OF VERMONT

INSTRUMENTATION
AND
MODEL FACILITY

BY: H.A. PRESTON (1967)
ADAPTED FROM BARRET (1947)

APPENDIX E

MAGNETIC SUSCEPTIBILITY RATIOS FOR SIX FORMAL RUNS

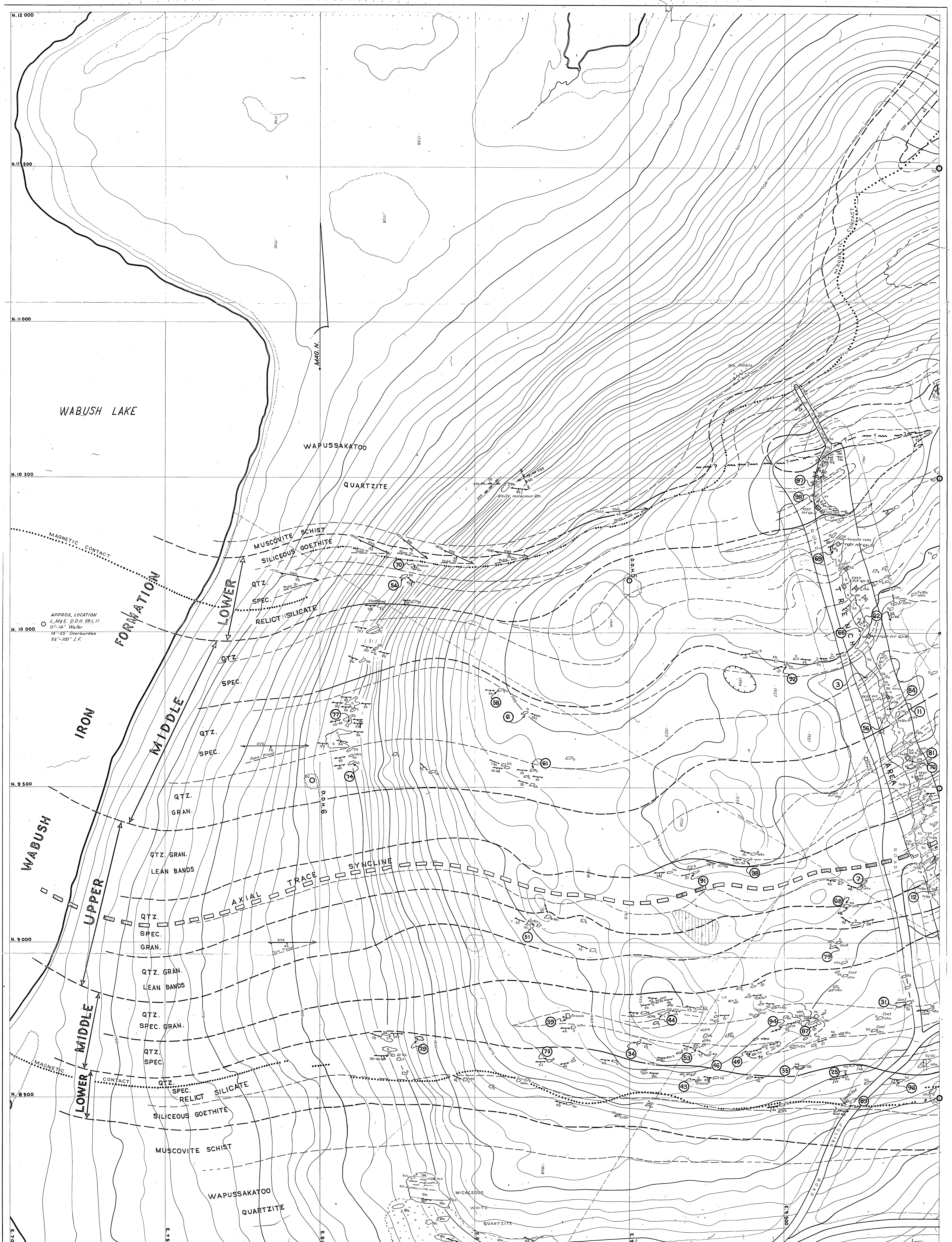
Ratio: $\dfrac{\text{Sample}}{\text{2\% Magnetite Standard}}$

Sample Number	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Range
M-1A	1.01	.95	.96	.84	.98	.98	IV
M-1B	.167	.03	.05	.03	.04	.03	I
M-2	.865	.856	.83	.83	.88	.89	IV
M-3A	.50	.52	.51	.51	.50	.51	III
M-3B	.05	.051	-*	-	-	-	I
M-4A	.18	.20	.20	.17	.14	.13	I
M-4B	.08	.065	.08	.014	.014	.03	I
M-5	.842	.846	.85	.81	.82	.82	IV
M-6	1.51	1.50	1.51	1.50	1.50	1.51	VII
M-9	.764	.74	.72	.80	.81	.82	IV
M-10	.79	.59	.59	.74	.74	.74	IV
M-11	.514	.51	.52	.47	.48	.49	II
M-12	1.59	1.50	1.53	1.51	1.51	1.53	VI
M-13	.83	.83	.84	.81	.84	.85	IV
M-14	.125	.12	.10	.11	.13	.10	I
M-15	.372	.344	.35	.38	.39	.377	II
M-16	.113	.13	.15	.11	.10	.10	I
M-17	1.86	1.95	1.98	1.94	1.97	1.98	VIII
M-18	.287	.35	.35	.32	.32	.32	II
M-19	.166	.16	.16	.18	.19	.178	I
M-20	.82	.75	.76	.80	.79	.784	IV

* Dropped bottle - sample lost

Runs 1 - 3 3 December - 3.30 p.m.   Runs 4 - 6 4 December 9.30 p.m.

Sample Number	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Range
M-21	.33	.36	.35	.31	.32	.324	II
M-22	.87	.85	.85	.81	.80	.81	IV
M-23	.82	.81	.82	.73	.73	.732	IV
M-24	.63	.63	.66	.60	.61	.606	III
M-25	.476	.47	.47	.45	.46	.47	II
M-26	.96	.98	1.00	.89	.89	.89	IV
M-27	.418	.472	.496	.467	.479	.479	II



WEST SHEET
(PLATE I)

236/127 1

236 (127)

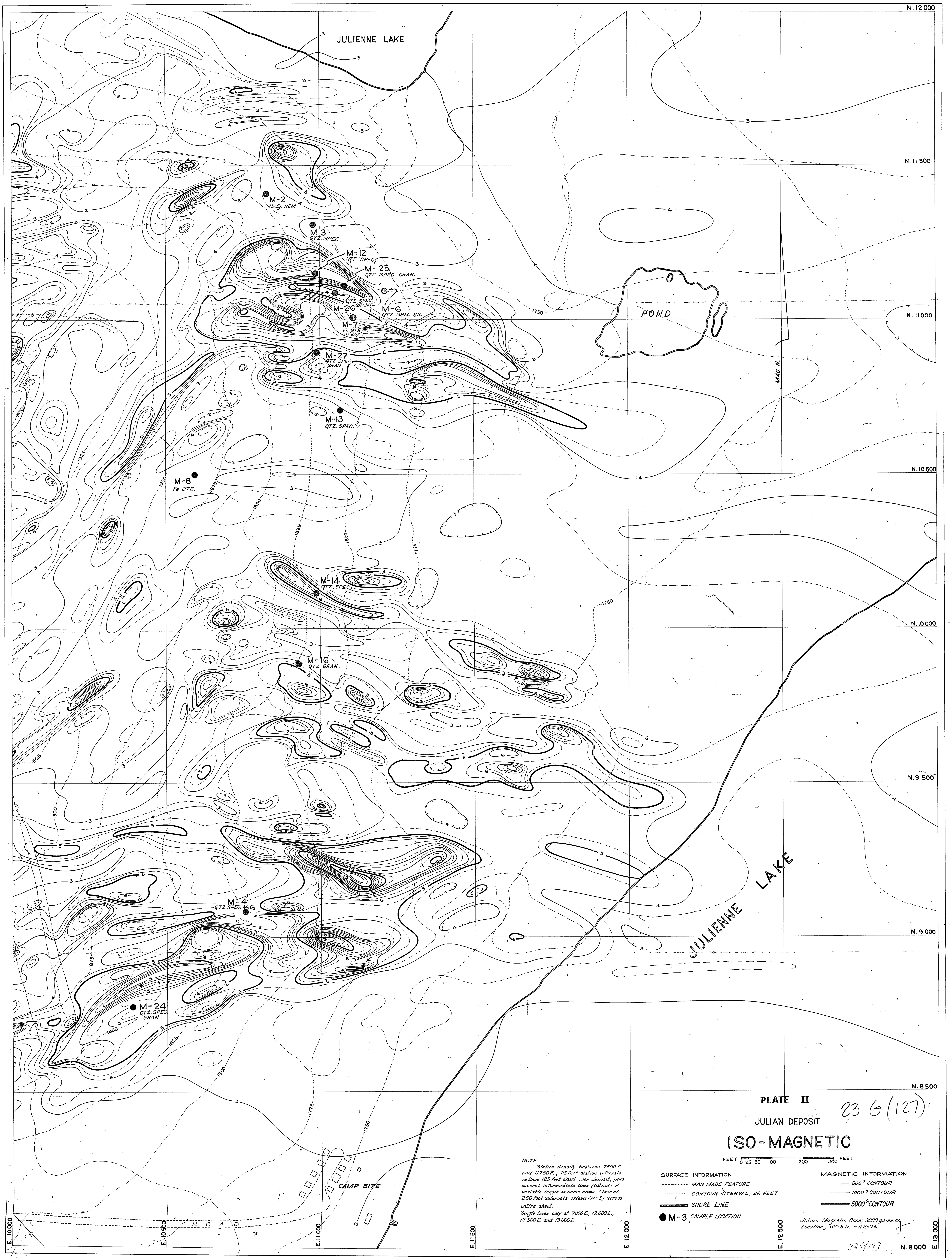


PLATE II

23 G (127)

JULIAN DEPOSIT

ISO-MAGNETIC

FEET 0 25 50 100 200 300 FEET

NOTE:
Station density between 7500 E. and 11.750 E., 25 feet station intervals on lines 125 feet apart over deposit, plus several intermediate lines (62 feet) of variable length in same areas. Lines at 250 foot intervals extend (N-S) across entire sheet.
Single lines only at 7000 E., 12 000 E., 12 500 E. and 13 000 E.

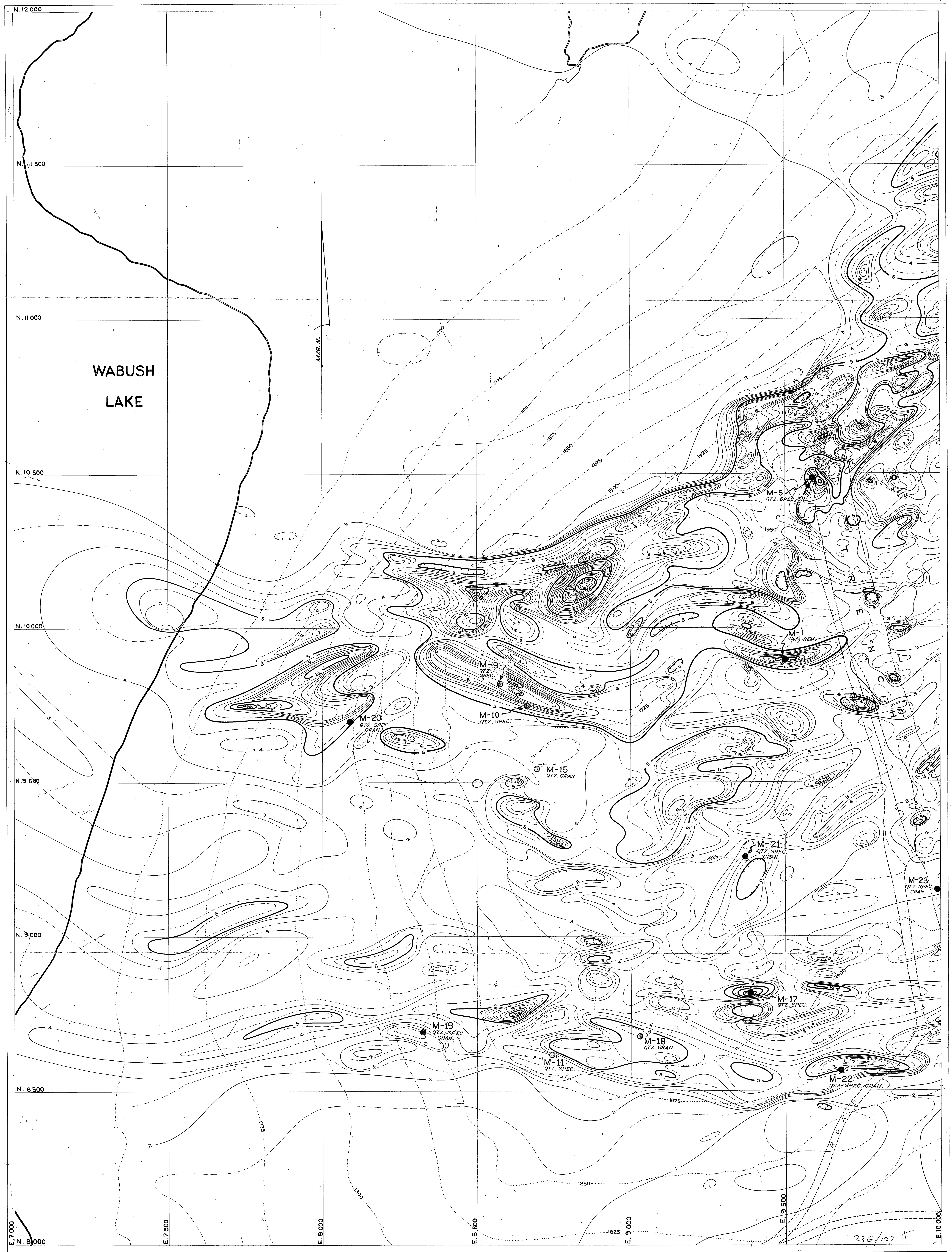
SURFACE INFORMATION
- - - - - - MAN MADE FEATURE
·········· CONTOUR INTERVAL, 25 FEET
━━ SHORE LINE
● M-3 SAMPLE LOCATION

MAGNETIC INFORMATION
— — — 500^{γ} CONTOUR
——— 1000^{γ} CONTOUR
━━━ 5000^{γ} CONTOUR

Julian Magnetic Base; 3000 gammas.
Location; 8275 N. - 11 250 E.

23G/127

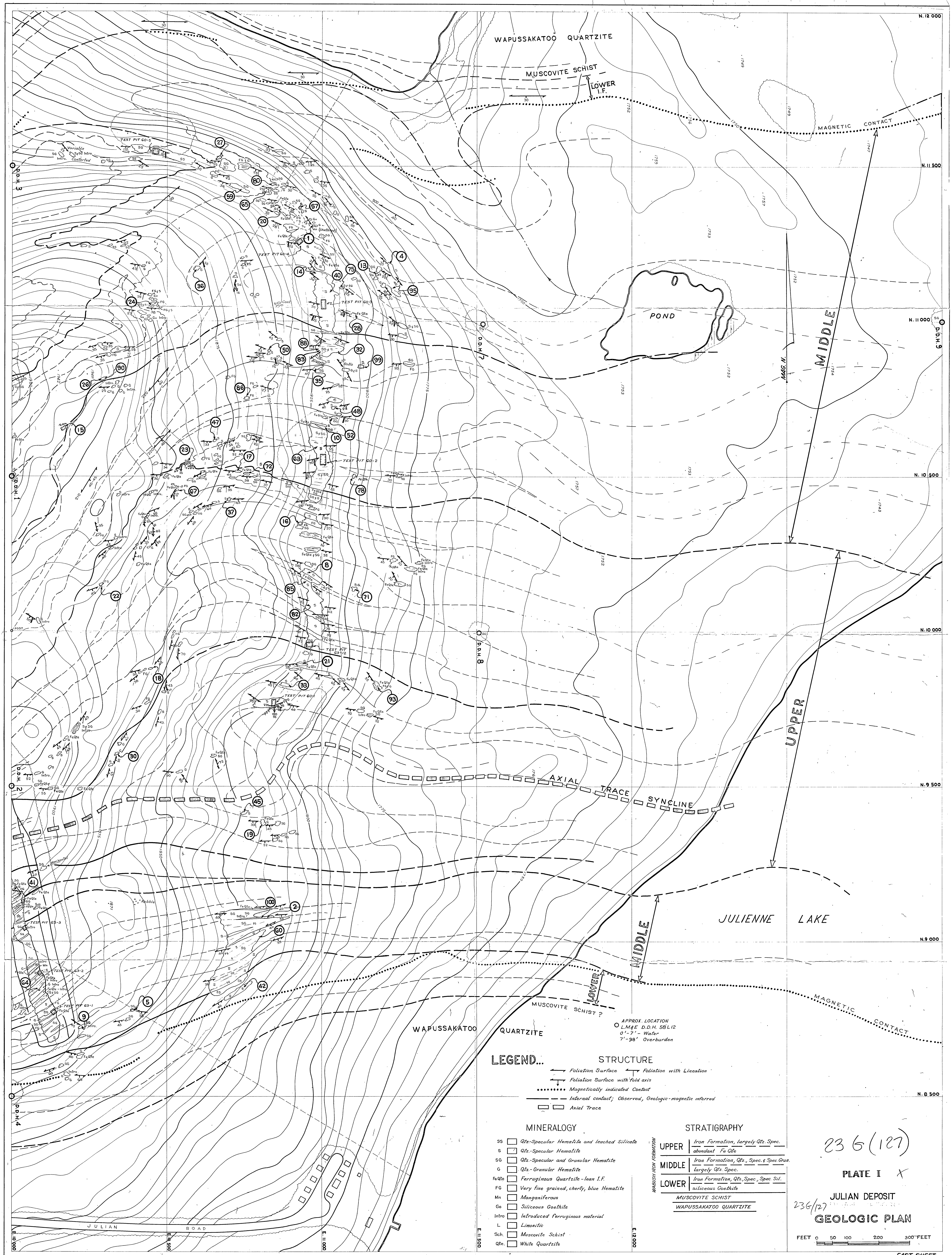
EAST HALF



236/127

23 G (127)

WEST HALF (PLATE



APPROX. LOCATION
L.M.&E D.D.H. 58L12
0'-7' - Water
7'-98' Overburden

LEGEND...

STRUCTURE

Foliation Surface
Foliation with Lineation
Foliation Surface with fold axis
Magnetically indicated Contact
Internal contact; Observed, Geologic-magnetic inferred
Axial Trace

MINERALOGY

SS	☐	Qtz-Specular Hematite and leached Silicate
S	☐	Qtz.-Specular Hematite
SG	☐	Qtz.-Specular and Granular Hematite
G	☐	Qtz.-Granular Hematite
FeQte	☐	Ferruginous Quartzite - lean I.F.
FG	☐	Very fine grained, cherty, blue Hematite
Mn	☐	Manganiferous
Go	☐	Siliceous Goethite
Intro	☐	Introduced ferruginous material
L	☐	Limonitic
Sch.	☐	Muscovite Schist
Qte.	☐	White Quartzite

STRATIGRAPHY

WABUSH IRON FORMATION	UPPER	Iron Formation, largely Qtz. Spec. abundant Fe Qte
	MIDDLE	Iron Formation, Qtz., Spec. & Spec. Gran. largely Qtz. Spec.
	LOWER	Iron Formation, Qtz., Spec., Spec. Sil. siliceous Goethite
	MUSCOVITE SCHIST	
	WAPUSSAKATOO QUARTZITE	

23 G (127)

PLATE I X

JULIAN DEPOSIT

236/127

GEOLOGIC PLAN

FEET 0 50 100 200 300 FEET

EAST SHEET