MINERALOGY AND PETROGRAPHY OF IRON FORMATION AT LAKE ALBANEL QUEBEC, CANADA

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Rudolph K. Hogberg

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MINERALOGY AND PETROGRAPHY OF IRON FORMATION AT LAKE ALBANEL, QUEBEC, CANADA

By

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ABSTRACT

The Temiscamie River area, on Lake Albanel, is located in the Precambrian shield of west-central Quebec, Canada. Results of laboratory examination of forty three thin sections, from diamond drill core fragments, revealed certain conclusions relative to textural relationships and mineralogic content of an iron formation.

Macroscopic study pointed out three divisions of the Temiscamie iron formation. Two divisions, the "Upper slate" and the "Lower slate", were used in background study. Microscopic examination of both the "slate" members indicates a striking similarity of alternating light chert and dark extremely fine grained carbonate bands.

The middle division, or "Iron formation", consists of anhedral carbonate grains in irregular patches and bean shaped granules composed entirely of carbonate or with varying amounts of chert, all surrounded by an equal-grained chert matrix. Magnetite occurs as irregular aggregates of anhedral and subhedral shaped grains and as rice-like grains in interlocking fabrics. Minor amounts of minnesotaite, stilpnomelane and muscovite were observed.

Petrographic modal analyses of twenty one thin sections from eleven diamond drill holes were made upon two arbitarily selected horizons at approximately uniform positions above

the stratigraphic "footwall" boundary. The estimates of mineral volume percentages determined from modal analyses were found to be valid upon comparison with metallurgical test results. Correlation of the total iron computations from modal analyses with metallurgical test total iron findings revealed the carbonate to be siderite and also that magnetite constitutes the overwhelming majority of the iron of the "Iron formation". No observable mineralogic changes were observed along the "oxide bearing member".

The general sequence of crystallization of a colloidal gel from an initial crystallized stilpnomelane to a finally crystallized fine grained chert groundmass is suggested.

A reducing environment is postulated for the formation of magnetite from pre-existing iron-rich minerals. Secondary alteration of the formations, from carbonate and magnetite to limonite and martite, is probably due to the influence of the present weathering surface.

ACKNOWLEDGMENTS

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He is also deeply indebted to the Albanel Minerals Limited for financial assistance, equipment, samples and much of the information used in the problem. In this connection the cooperation and suggestions of Mr. B. H. Boyum and Mr. E. J. Rex were invaluable.

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INTRODUCTION

Location and Accessibility

Exposures of iron bearing sedimentary formation have been found at Lake Albanel in west-central Quebec. Many geologists are now of the opinion that these rocks are a continuation of a trend that may be traced 400 miles southwest from similar sedimentary iron occurrences in the Labrador trough.

The Albanel lake area is in the Mistassini Territory,

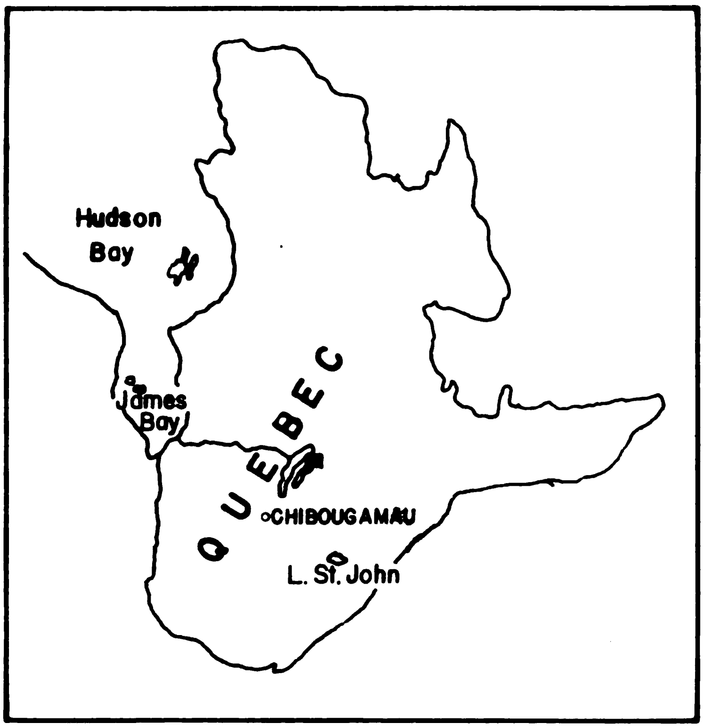


Fig. 1 Location of the Temiscamie River Area

Province of Quebec, Canada, approximately 250 miles directly east of the southern extremity of James Bay. Lake Albanel is the smaller and more southeasterly of two large northeast trending lakes; the other is Lake Mistassini. These lakes are the headwaters of the Rupert River which flows into James Bay.

A 145-mile gravel road from Lake St. John to Chibougamau affords access to a point 90 air miles southwest of the area.

The inhabitants, a Mistassini Cree band of Indians, exploit the natural resources of fish and game for food and other means of livelihood.

Physical Features and Climate

This region displays moderate relief and poorly integrated drainage, both are characteristic of the Canadian

Fig. 2 Picture of the southwest portion of the Temiscamie River area

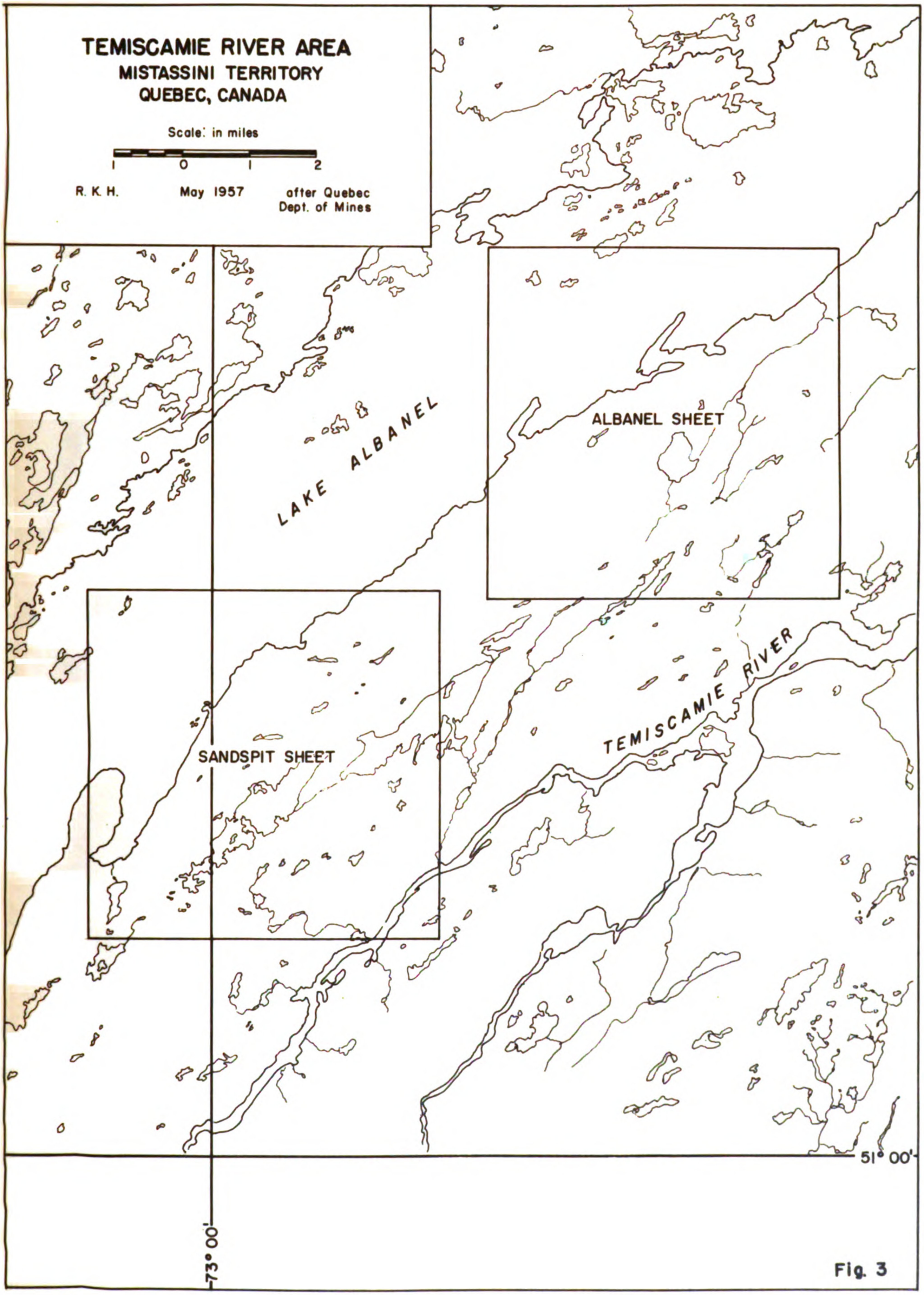

TEMISCAMIE RIVER AREA
MISTASSINI TERRITORY
QUEBEC, CANADA
Scale: in miles
1 0 1 2
R. K. H.
May 1957
after Quebec
Dept. of Mines
LAKE ALBANEL
ALBANEL SHEET
SANDSPIT SHEET
TEMISCAMIE RIVER
51° 00'
73° 00'

Fig. 3

shield. Figure 2 is a aerial photograph showing the general land forms of the area.

Glacial deposits, variable in thickness, conceal the bed rock with "sand plains", drumlins and discontinuous eskers.

Heavy forests of black spruce and balsam envelop the region, except in the muskeg portions. White birch grows upon the low glacial ridges.

The summer season is short. Ice on the large lakes breaks up in early June, and these bodies of water freeze again in October. At times strong southwest winds make canoe travel on the large lakes impossible. Summer rainfall is quite heavy and frequent and temperatures are moderate. The winters are cold with temperatures ranging down to - 40° F.

Exploration History

This region was first mentioned in the literature by explorers, missionaries and traders in their records of quests for a route west from Lake St. John to James Bay (Mawdsley and Norman, 1935).

Early reports on the geology of the region were written by Richardson in 1871 who reported flat lying limestones at Lake Mistassini, and by Low in 1886, who called the sedimentary formation Cambrian in age because of the resemblance to Cambrian age strata on the east side of Hudson Bay. Barlow, in 1910, called the sediments Ordovician upon finding possible biogenetic structures (Neilson, 1953).

In more recent geological exploration, Norman (1940) described the contact of the sedimentary sequence with the Grenville sub-province. Neilson and Wahl mapped the geology of the Albanel and Temiscamie River areas in 1947 and 1948. Their reports (Neilson, 1953 and Wahl, 1953) are a description of the igneous and metamorphic rocks, the stratigraphy of the Precambrian Mistassini series, structural features, and the economic potential of the two areas.

Regional Geologic Setting

This discussion of the general geology is a summary of the works of Neilson (1953), Norman (1940) and Wahl (1953).

Rocks of the region consist of sedimentary strata overlying a granite and gneiss complex. The sediments and basement rocks are intruded by pegmatites, and alkaline and basic plutons (Table I).

The basement complex of early Precambrian granites, orthogneisses and paragneisses is exposed in the southeast portion of Figure 3.

TABLE I

STRATIGRAPHIC COLUMN OF THE TEMISCAMIE RIVER AREA

Rock unit		Character of unit	thickness in feet
Pleistocene		Stratified sands and gravel, till	varies
Unconformity			
Intrusive complex		Alkaline and basic intrusives Pegmatite	
Mistassini series	Temiscamie iron formation	"Upper slate"- cherty carbonate and graywacke	
		"Iron formation"- cherty iron carbonate	220'
		"Lower slate"- cherty carbonate and argillite Quartzite	50' 35'
	Disconformity ?		
	Upper Albanel formation	Sandy gray dolomite	2000'
	Disconformity ?		
	Lower Albanel formation	Shaly gray dolomite Massive gray dolomite	4000' to 7800' ?
Unconformity ?			
Granite and gneiss complex		Granite Orthogneiss Paragneiss	

after Neilson (1953) and Wahl (1953)

During later Precambrian time dolomites and "Iron formation" of the Mistassini series were deposited. The dolomite succession is divided into two well stratified members by a disconformity. The Lower Albanel formation consists of dark gray, ferruginous and shaly beds and is limited areally to the Mistassini lake basin. The Upper Albanel formation, confined to the Lake Albanel area, is composed of sandy dolomites. The uppermost member of the Upper Albanel formation contains possible cryptozöon structures.

Overlying and separated by another disconformity is the basal quartzite of the Temiscamie iron formation. This pure quartzite is persistent in the vicinity of Lake Albanel. It is followed by the argillite and cherty carbonate beds of the "Lower slate", which in turn grades into the "Iron formation". The "Upper slate" is composed of fine grained cherty carbonate and graywacke.

The sediments of the Mistassini series strike northeast and dip gently to the southeast. This simple structure is interrupted locally by small synclines, anticlines and faults. The angle of dip of the beds increases very rapidly southwestward towards a zone of intense shearing and crushing which marks the so called "Grenville front". It is generally agreed that the Grenville gneisses in this area have been thrust northwestward over the sedimentary strata.

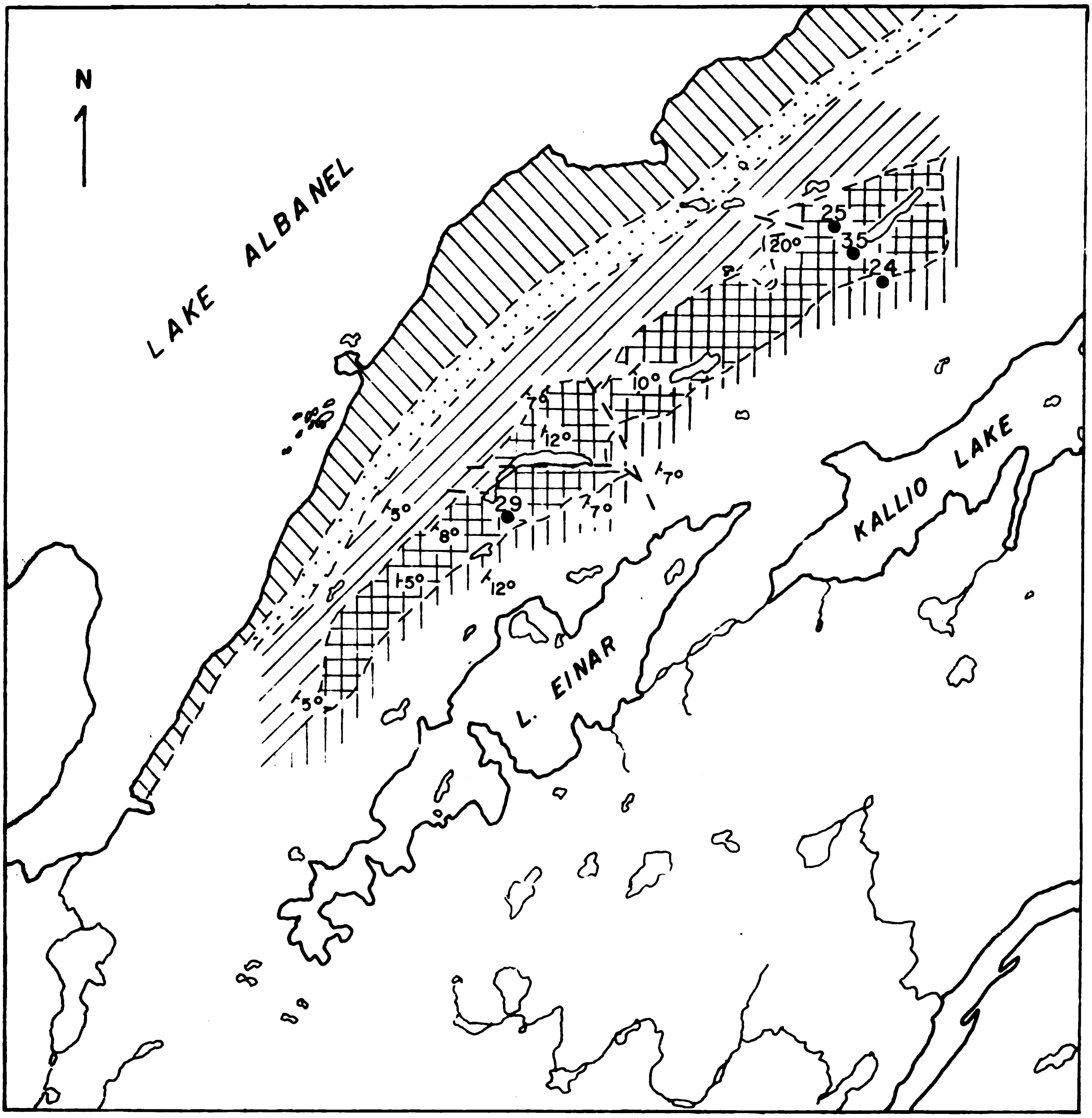
Presently the correlation of the rocks of the area with similar occurrences is obscure. Lack of field mapping between the Albanel region and other geological provinces which contain iron formation necessitates considering this region as isolated geologically until more information can be gathered.

Purpose and Scope

This problem was suggested by Albanel Minerals Ltd. upon request by the author. An interest was developed in a detailed examination during the course of field work on the "Iron formation" in the Albanel lake area during the summer of 1956. Anomalous fluctuations in the hematite/magnetite ratio pointed out the Albanel and Sandspit Sheets of the Temiscamie River area as critical areas for further examination (Figures 4 and 5).

This thesis reports the results of a laboratory study of core fragments from 11 selected diamond drill holes (Figures 6 and 7). The cores were relogged by the author and sampled in certain horizons. Forty three thin sections were studied. The author also determined modal analyses of 21 thin sections.

The purpose of this investigation is to ascertain the petrography and significant mineralogic gradation of the "oxide bearing member" of the Temiscamie iron formation.



GEOLOGIC MAP OF SANDSPIT SHEET

TEMISCAMIE RIVER AREA
QUEBEC, CANADA

Scale: in feet

2000 0 2000 4000

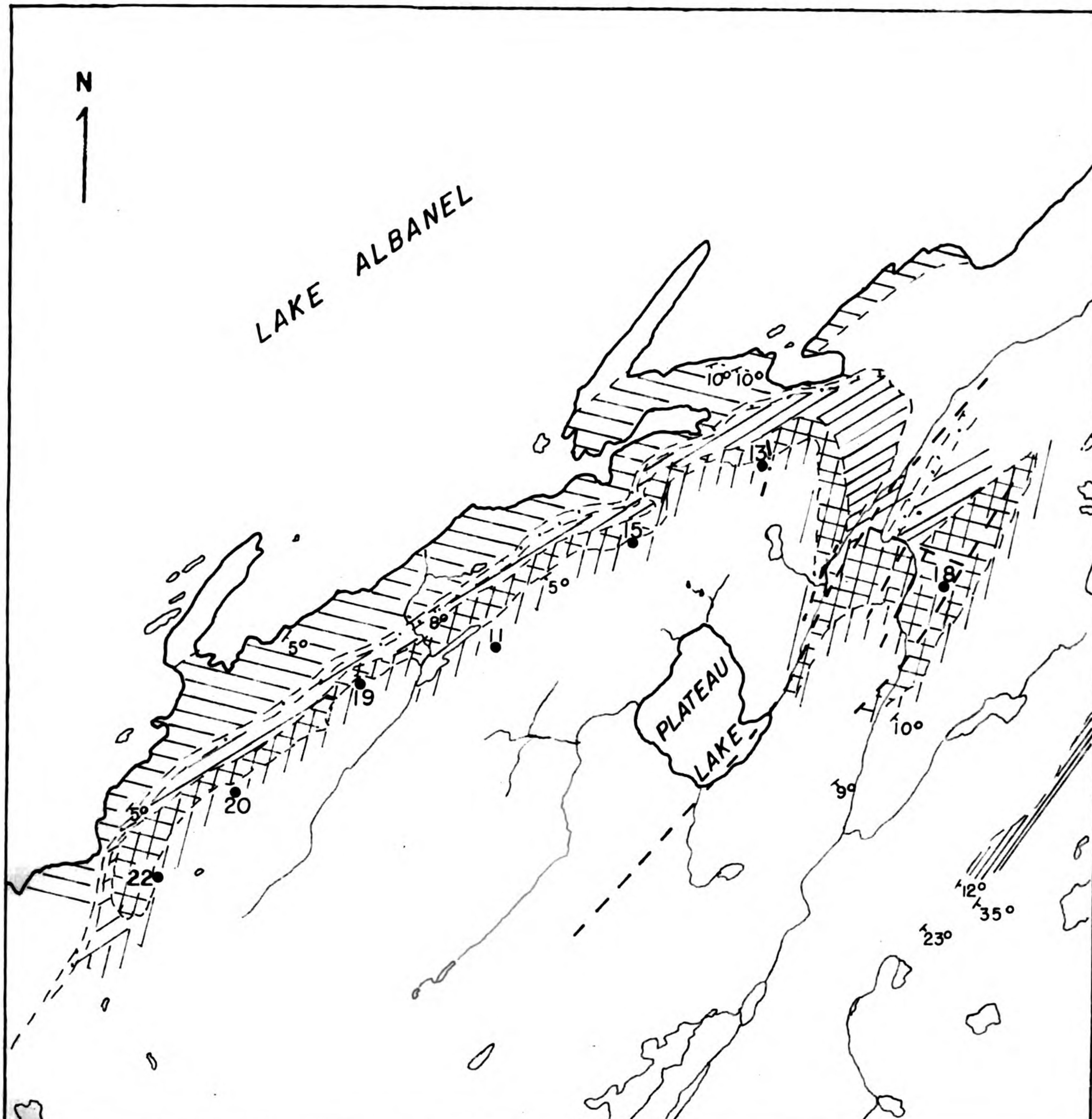
D.D.H. ● STRIKE & DIP ┬ FAULT — —

R.K.H. May 1957 after Albanel Minerals Ltd.

MISTASSINI SERIES

- SLATE & GRAYWACKE
- CHERTY CARBONATE
- "IRON FORMATION"
- CHERTY CARBONATE & ARGILLITE
- QUARTZITE
- DOLOMITE

Fig. 4



GEOLOGIC MAP OF ALBANEL SHEET

TEMISCAMIE RIVER AREA
QUEBEC, CANADA

Scale: in feet

2000 0 2000 4000

D.D.H. ● STRIKE & DIP ┬ FAULT — —

R.K.H. May 1957 after Albanel Minerals Ltd.

MISTASSINI SERIES

- SLATE & GRAYWACKE
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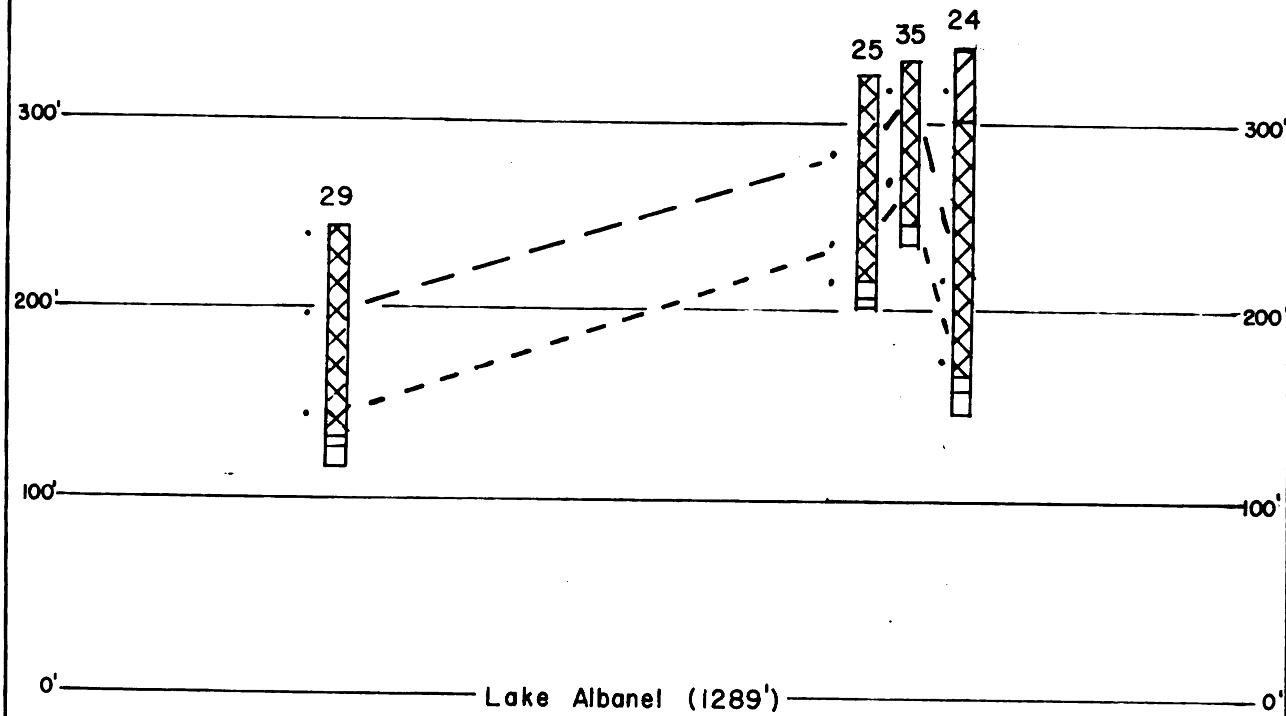
- QUARTZITE
- DOLOMITE

Fig. 5



VERTICAL CROSS SECTION
OF DIAMOND DRILL HOLES
SANDSPIT SHEET
TEMISCAMIE RIVER AREA
QUEBEC, CANADA

Scale

VERTICAL 1"= 100'
HORIZONTAL 1"= 4000'
V. E. = 40 TO 1

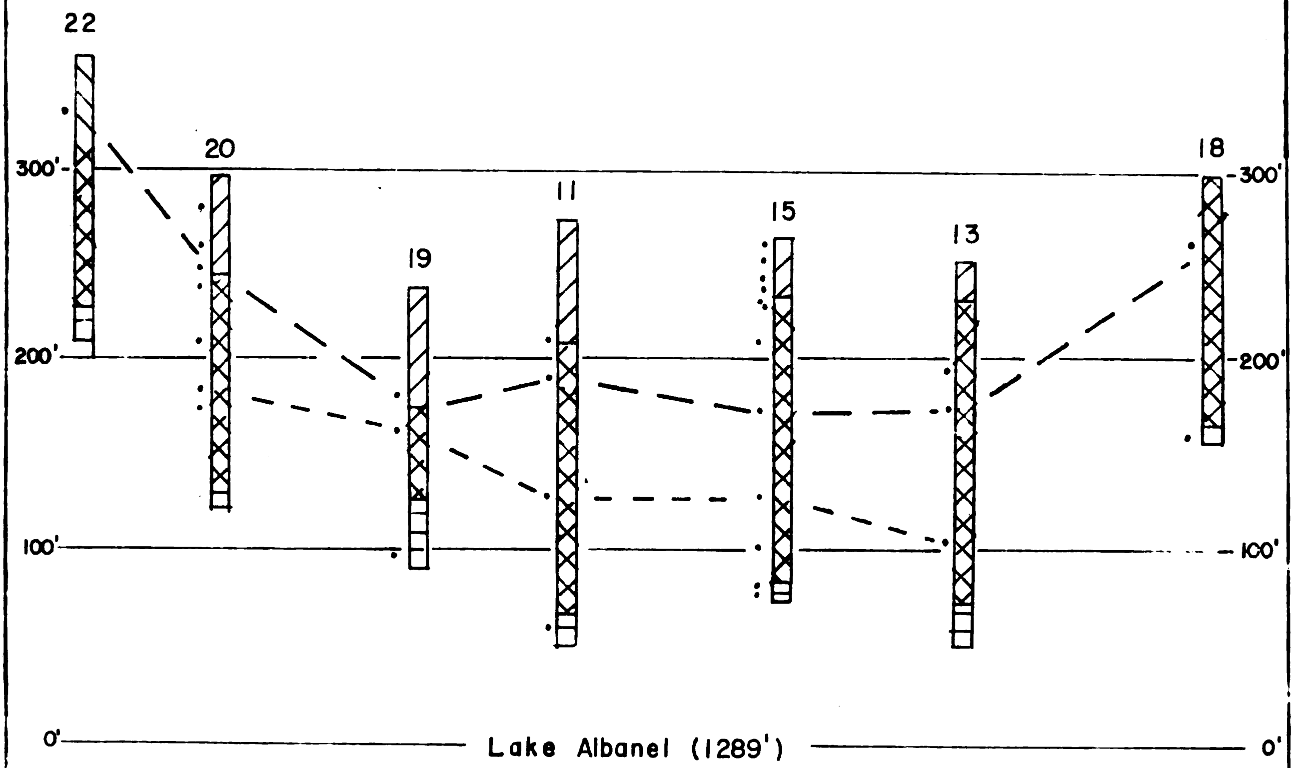
SAMPLE LOCATIONS •
100' HORIZON — —
50' HORIZON — — —

TEMISCAMIE IRON FORMATION

CHERTY CARBONATE
"IRON FORMATION"
CHERTY CARBONATE & ARGILLITE

R. K. H. May 1957 permisson of
Albanel Minerals Ltd.

Fig. 6



VERTICAL CROSS SECTION OF DIAMOND DRILL HOLES

ALBANEL SHEET
TEMISCAMIE RIVER AREA
QUEBEC, CANADA

Scale

VERTICAL 1"= 100'
HORIZONTAL 1"= 4000'
V. E. ≐ 40 TO 1

SAMPLE LOCATIONS ·
100' HORIZON — —
50' HORIZON – – –

TEMISCAMIE IRON FORMATION

CHERTY CARBONATE
"IRON FORMATION"
CHERTY CARBONATE & ARGILLITE

R. K. H. May 1957 permisson of Albanel Minerals Ltd.

Fig. 7

GLOSSARY OF ABBREVIATIONS FOR TABLES II THROUGH X

Al - Albanel Sheet

alt - secondary oxidation and hydration

anh - anhedral

av - average

bd and bds - band and bands

brn - brown

Carb - carbonate

CONT. - continued

dia - diameter

euh - euhedral

grn - green

irr - irregular

Lim - limonite

ny mag - normally magnetic

lt - light

Mag - magnetite

mag - magnetic

maj - majority

max - maximum

med - medium

Minn - minnesotaite

Musc - muscovite

ny mag - normally magnetic

Qtz - quartz

Stilp - stilpnomelane

subh - subhedral

tr - trace

Ss - Sandspit Sheet

vy ly mag - very leanly magnetic

X - crossed

yel - yellow

Banding

thin banded - less than 1/8"

medium banded - 1/8" to 3/8"

thick banded - 3/8" to 6"

massive - over 6"

TABLE II
ANALYSES OF 100' HORIZON OF "IRON FORMATION"

Petrographic Modal Analyses						
Mineral	Ss #29-45'	Ss #25-40'	Ss #35-17'	Ss #24-125'	Al #22-30'-40'	Al #20-60'
Quartz	24 %	64 %	74 %	63 %	50 %	58 %
Carbonate	39	7	8	13	8	15
Magnetite	37	29	18	19	34	27
Silicates	tr			5	8	tr
Muscovite						
Total	100	100	100	100	100	100
Core and Thin Section Analyses						
Core	ny mag; lt gray matrix; patches & bds of Mag	ny mag; gray -pink; Mag specks inter-spersed domly in the matrix	ny mag; gray ; irr patches of Carb & Mag	ly mag; lt gray; yel-buff patches of Carb; specks of Mag	ny mag; lt gray; specks and patches of Mag	ny mag;brn - gray matrix; styololitic like thin wavy bds of Mag
Thin Section (1) Chert (2) Carb (3) Mag (4) Minn (5) Stilp (6) Musc (7) alt	(1) maj of 0.006 mm dia grains; re-mainder 0.01 mm in dia (2) small anh grains in patches & bds (3) rice like grains in interlocking irr aggregates (4) colorless needles max 0.03 mm long (7) minor	(1) maj 0.003 mm remainder 0.03 mm in dia (2) small anh grains in in bean shap-ed granules (3) similar to Ss-#29-45' (7) yel to orange-red (under re-flected light) also minor Martite	(1) similar to Ss-#25-40' (2) highly clouded anh grains in patches (3) subh to anh grains in irr masses (7) extensive Lim; rim re-placement of Mag by Martite	(1) matrix 0.003 mm to 0.2 mm in dia (2) anh grain in oval shaped gran-ules (3) needles & anh grains in irr aggre-gates (4) needles av 0.06 mm long in Chert (5) yel-grn & yel-brn blades av 0.2 mm long (7) none ob-served	(1) similar to Ss-#29-45' (2) similar to Ss-#29-45' (3) in the form of Carb & Minn grains (4) similar to Ss-#24-125' (7) yel Lim staining as seen under reflected light	(1) maj of 0.01 mm and remainder 0.04 mm in dia (2) minor amount of individual anh grains (3) similar to Ss-#29-45' (4) similar to Ss-#24-125 (5) grn high-ly pleochroic blades in Carb & Chert (7) minor amount

TABLE III
ANALYSES OF 100' HORIZON OF "IRON FORMATION" (CONT.)

Petrographic Modal Analyses						
Mineral	Al #19-50'-60'	Al #11-80'-85'	Al #15-91'	Al #13-70'-80'	Al #18-30'-40'	Al #15-57'
Quartz	40 %	15 %	46 %	64 %	25 %	33 %
Carbonate	52	30	24	1	53	28
Magnetite	8	52	29	34	10	35
Silicates		3	1		12	1
Muscovite		tr		1		3
Total	100	100	100	100	100	100
Core and Thin Section Analyses						
Core	vy ly mag; pink stained med gray matrix	ny mag; pink-gray; patches & bds of Carb	ly mag; dark gray; pink staining; distinctive patches of Carb	ny mag; pink-gray; brn & black patches	vy ly mag; lt brn-gray to lt gray; bds of Carb & Mag	ny mag; lt gray to pink-gray; patches & bds of Mag
Thin Section (1) Chert (2) Carb (3) Mag (4) Minn (5) Stilp (6) Musc (7) alt	(1) 0.010 mm 0.1 mm in grain dia (2) aggregate of anh grains (3) dust size euh & larger subh to anh grains (7) minor Lim staining & little Martite	(1) maj of the 0.006 mm grain size (2) anh grains in patches; rhombs exhibiting lamellae (3) interlocking aggregates of rice like grains (4) or (5) lt-grn to lt-brn plates (6) minor non-pleochroic scales (7) minor	(1) similar to Al-#11-80'-85' (2) similar to Al-#11-80'-85' (3) in blades & anh grains in irr masses (4) yel variety (7) extensive Lim staining; minor Martite rim replacement of Mag	(1) overwhelmingly of the 0.006 mm grain size; 0.010 mm grains associated with Carb (2) minor anh grains (3) anh grains (6) low relief colorless; scales and blades (7) orange-red Lim; Martite after Mag	(1) 0.006 mm to 0.04 mm in dia size (2) patches & bands of anh grains (3) similar to Al-#15-91' (4) fine colorless needles; max 0.04 mm long (5) yel-brn to black av 0.2 mm long blades; in radial bundles (7) little	(1) similar to Al-#19-50'-60' (2) bean shaped granules of anh grains (3) anh grains in interlocking patches & chains (5) med grn blades in radial arrangement (6) blades in Mag ringed granules with Carb & Qtz (7) minor

TABLE IV

ANALYSES OF 50' HORIZON OF "IRON FORMATION"

Petrographic Modal Analyses				
Mineral	Ss #29-95'	Ss #25-90'	Ss #35-65'	Ss #24-165'
Quartz	62 %	75.5 %	49 %	56 %
Carbonate	15	1.0	20	26
Magnetite	23	23.0	31	16
Silicates		0.5		2
Muscovite				
Total	100	100.0	100	100
Core and Thin Section Analyses				
Core	ny mag; med gray; interspersed red, yel & black specks	ny mag; patches of Mag throughout the med gray matrix	ny mag; dark gray to med gray; buff bds of Carb	ny mag; lt gray; bloches & bds of Carb; specks of Mag
Thin Section (1) Chert (2) Carb (3) Mag (4) Minn (5) Stilp (6) Musc (7) alt	(1) 0.006 mm to 0.03 mm in grain dia (2) patches of anh grains (3) rice like grains in interlocking irr aggregates (7) slight amount of Lim staining & minor Martite	(1) similar to Ss-#29-95' (2) scattered individual anh grains (3) irr patches & bds of anh grains; minor euh dust size grains (4) or (5) olive grn non-pleochroic & non-isotropic patches (7) similar to Ss-#29-95'	(1) 0.003 mm to 0.1 mm in dia size (2) anh grains in bean shaped granules av 0.6 mm dia; rhombs max 2 mm long of poikilitic texture with included large size Qtz grains (3) abundant anh grains (7) similar to Ss-#29-95'	(1) similar to Ss-#29-95' (2) maj anh Carb av 0.6 mm long ½ as wide (3) rim replacement of peripheral grains of Carb granules (4) similar to Ss-#25-90' (7) minor

TABLE V

ANALYSES OF 50' HORIZON OF "IRON FORMATION" (CONT.)

Petrographic Modal Analyses					
Mineral	Al #20-113'	Al #19-70'-80'	Al #11-140'-150'	Al #15-137'	Al #13-140'-150'
Quartz	51 %	79 %	24 %	56 %	31 %
Carbonate	10	5	54	23	53
Magnetite	38	16	22	21	16
Silicates	1			tr	
Muscovite					
Total	100	100	100	100	100
Core and Thin Section Analyses					
Core	ly mag; pink-white; bds of Carb & specks of Mag	ly mag; gray matrix	ly mag; med gray colored matrix	ly mag; lt gray; yel-white Carb; patches & specks of Mag	ly mag; lt gray; thin banded ; abundant specks of Mag
Thin Section (1) Chert (2) Carb (3) Mag (4) Minn (5) Stilp (6) Musc (7) alt	(1) matrix of 0.01 mm to 0.125 mm in dia (2) anh grains av 0.6 mm long (3) needles & anh grains interlocked in bds (4) needles in Chert only (5) yel-brn blades in Carb & Chert (7) little Lim staining & minor Martite	(1) similar to Al-#20-113' (2) patches of clouded anh grains; rhombs max 2 mm long & 2/3 as wide (3) saw-toothed boundary with Carb (7) ruby-red (under reflected light); Martite after Mag	(1) maj of 0.006 mm dia grains (2) similar to Al-#19-70'-80' (3) similar to Al-#19-70'-80' (7) little alteration observed	(1) similar to Al-#20-113' (2) scattered patches with irr boundaries; rhombs exhibiting pleochroic lamellae (3) anh grains & needles in irr masses (4) minor med grn plates (7) minor Martite; no Lim observed	(1) similar to Al-#11-140'-150' (2) similar to Al-#19-70'-80' (3) anh grains; dust size euh grains (7) extensive Lim staining; also euh dust size & rim Martite

TABLE VI
ANALYSES OF SAMPLES OF "IRON FORMATION"

	Core and Thin Section Analyses				
	Ss #29-4'	Al #20-50'	Al #15-37'	Al #15-37½'	Al #13-50'-60'
Core	ny mag; brn-gray; thin bds of Mag	ny mag; dark gray colored matrix	ny mag; pink-gray matrix	similar to Al-#15-37' but larger granules max 1.5 mm in dia	ny mag; gray; patches & bds of Mag
Thin Section (1) Chert (2) Carb (3) Mag (4) Minn (5) Stilp (6) Musc (7) alt	(1) similar to Al-#15-37' (2) bean shaped gran- of anh Carb & Qtz (3) euh & anh grains & ag-gregates (5) very minor amount (7) abundant oval Lim ? rings	(1) similar to Al-#15-37' (2) similar to Ss-#29-4' (3) similar to Ss-#29-4' (4) associated with the coarse grain-ed Chert (5) yel-grn blades in Carb & Chert (7) very little observed	(1) up to 0.5 mm in granul-es surrounded by 0.006 mm dia grains (2) anh cloud-ed grains; rhombs max 0.06 mm long & almost as wide (3) euh to anh grains up to size of Carb & Qtz granules (7) extensive Lim staining gives an oolite appearance; minor Martite	similar to Al-#15-37'	(1) similar to Al-#15-37' (2) similar to Ss-#29-4' (3) similar to Ss-#29-4' (7) med Lim staining; very minor Martite

TABLE VII

ANALYSES OF SAMPLES OF "IRON FORMATION" (CONT.)

Core and Thin Section Analyses	Al #20-88'	Al #20-122'	Al #15-162'
Core	ly mag; pink-gray; irr spaced thin bds of Mag & Carb	ly mag; patch-es & bds of Mag & Carb; specks of Mag in both	ly mag; lt to dark gray; specks & bds of Mag
Thin Section (1) Chert (2) Carb (3) Mag (4) Minn (5) Stilp (6) Musc (7) alt	(1) maj 0.01 mm dia grains (2) minor irr patches of anh grains (3) anh grains (4) or(5) irr olive grn patches (7) little observed	(1) matrix of 0.2 mm dia grains (2) similar to Al-#20-88' (3) similar to Al-#20-88' (4) minor; max 0.2 mm long (7) little	(1) similar to Al- #20-88' (2) similar to Al-#20-88' (3) similar to Al-#20-88' (4) colorless needles (5) med grn blades av 0.4 mm long (6) contains particles of Chlorite blades; brilliant yel,grn,red colors be-tween X nicols; in scales (7) minor amount

TABLE VIII
ANALYSES OF "UPPER SLATE"

	Core and Thin Section Analyses			
	Ss #24-20A	Al #20-18'	Al #15-6'	Al #15-13'
Core	non-mag; alternating lt & dark thin bds	ly mag similar to Ss-#24-20A	non-mag; med gray; med banded	non-mag; med to thick banded
Thin Section (1) Chert (2) Carb (3) Mag (4) Minn (5) Stilp (6) Musc (7) alt	(1) maj less than 0.003 mm in dia (2) patches of anh clouded grains (4) minor needles av 0.15 mm long (5) med grn highly pleochroic blades max 0.3 mm long (7) minor	(1) matrix of 0.006 mm to 0.3 mm in dia (2) anh grains in patches; rhombs max 0.5 mm long (4) patches of a med grn fabric of needles (5) blades in fine grained Carb (7) little observed	(1) lt bd has minor amount of fine grains; dark bds 0.006 mm to 0.2 mm in dia (2) lt bd very fine grained with minor irr Pyrite grains also bursts of Graphite ? ; dark bds anh grains up to a max 0.3 mm long (3) very minor amount at border of the lt and dark bds (7) minor	(1) similar Ss-#24-20A (2) maj of anh grains with small Pyrite grains; also scattered rhombs (5) dark grn blades (7) minor amount observed

TABLE IX
ANALYSES OF "UPPER SLATE" (CONT.)

Core and Thin Section Analyses				
	Al #20-38'	Al #11-60'-65'	Al #15-22'	Al #15-29'
Core	no core	ly mag; brn gray to pink-gray matrix; thin wavy bds of Mag	non-mag; lt gray with dark thin bds of Carb	non-mag; thin banded
Thin Section (1) Chert (2) Carb (3) Mag (4) Minn (5) Stilp (6) Musc (7) alt	(1) matrix av 0.1 mm dia (2) anh grains in rounded granules av 2 mm in dia (4) very minor amount; av 0.025 mm long (5) minor; max 0.3 mm long (7) med amount of Lim staining	(1) 0.06 mm to 0.125 mm dia grains (2) oval granules of anh grains; scattered rhombs (3) euh to anh grains in aggregate chains (4) in Chert only & bordering the Carb (5) yel-brn blades (7) extensive Lim staining	(1) minor Qtz in fine grained bds; 0.006 mm to 0.25 mm in coarse bds (2) minute anh grains in fine grained portion; coarse portion anh grain also rhombs of poikilitic texture with included Qtz (7) minor amount	(1) similar to Al-#15-22' (2) extremely fine grained Carb with minor Pyrite & Graphite ? (5) med grn individual highly pleochroic blades (7) little observed

TABLE X

ANALYSES OF "LOWER SLATE"

Core and Thin Section Analyses	Ss #25-110'	Al #19-140'-150'	Al #11-207'-220'	Al #15-182'	Al #15-187'	Al #18-140'-150'
Core	non-mag; lt gray; patches of yel-buff carbonate	non-mag; med gray	vy ly mag; dark gray; wavy thin to thick banded	ly mag; bursts of buff colored Carb	similar Al-#15-182'	non-mag; med gray colored
Thin Section (1) Chert (2) Carb (3) Mag (4) Minn (5) Stilp (6) Musc (7) alt	(1) 0.003 mm to 0.05 mm in dia grains (2) cloudy anh grains gray-buff colored between X nicols; in bds & patches (4) very minor av 0.125 mm long needles (5) similar to Al-#19-140'-150' (7) slight Lim staining of the Carb.	(1) minor amount (2) similar to Ss-#25'-110' (4) abundant colorless needles in the Chert (5) both yel-grn & yel-brn blades av 0.2 mm long in Chert & Carb; in radial bundles (7) minor	(1) matrix of lt colored; 0.006 mm dia (2) fine anh grain masses (3) very minor amount (4) similar to Ss-#25'-110' (5) similar to Al-#19-140'-150' (7) minor amount	(1) similar to Al-#19-140'-150' (2) scattered rhombs; bds of anh grains (4) abundant lt blue-green needles in Chert (7) minor amount	(1) similar to Al-#19-140'-150' (2) similar to Al-#11-207'-220' (4) similar to Al-#11-207'-220' (5) similar to Al-#11-207'-220' (7) minor	(1) similar to Al-#19-140-150' (2) similar to Ss-#25'-110' (4) abundant fine needles (5) similar to Al-#19-140'-150' (7) little observed

THE TEMISCAMIE IRON FORMATION

Introduction

The cores upon which this study is based were drilled during the summer field season of 1954. At that time the company retained representative core sections and used the remaining portions for metallurgical testing.

For the investigation the author selected samples from diamond drill holes with the greatest footage in the "Iron formation". A detailed macroscopic examination of the core fragments from 11 holes revealed three stratigraphic divisions. Two of the divisions, the "Upper slate" and the "Lower slate", are considered separately from the "oxide bearing member".

Thin and polished sections available for examination, were previously prepared for a cursory survey, by the company, of the formation in the Sandspit and Albanel Sheet areas. The writer compared the distribution of the various sampled horizons with the recognized stratigraphic divisions. This information was consolidated with studies of additional thin and polished sections to provide an adequate coverage for the problem. Samples of the "Iron formation" at approximately 50' and 100' positions above the stratigraphic "footwall" boundary were chosen for microscopic study and petrographic modal analyses. Additional random rock sections from the "oxide bearing member" provided further data. Core fragments from the two "slate" members were selected for background microscopic examination.

Methods and Procedures

The author examined the thin sections by the common petrographic procedures. Study of polished sections and core sections supplemented the thin section work.

A six-spool continuous line integrating stage was employed for the modal analyses. Lines were run perpendicular to the sedimentary banding at two millimeter intervals. To determine satisfactory length of traverse for reliable measurements, the author computed the percentages of each mineral on every component line. The traversing was terminated when more than six lines were completed and the percentages of all the minerals on any two consecutive lines held constant. Total traverse lengths varied from 77.89 to 167.02 millimeters and averaged 114.66 millimeters. If less than 0.5 % of a mineral was measured it was listed as a trace in the modal analyses tabulations.

Petrographic modal analysis is based on the theory that parallel line traverses of thin sections are consistent estimators of true population or mineral mean. The analysis is unbiased if the traverse length is sufficiently large. Chayes (1956) describes two types of errors in the estimation of the mean of minerals in rocks analyzed by the continuous line integrator. The reproducibility or counting error of the thin section is a combination of process, instrument, identification and tabulation conventions. To limit this error the same procedures were followed on each component line. The minerals were easily identified and tabulation conventions were consistent. The second or analytical type is the random error of the analysis in estimating the mineral composition of the core from which the thin section was cut. Finally the estimate of volume of each mineral from thin section analysis is what Chayes (1956) has named the Dellesse or area-volume relation. He states:

> "Thus, the ratio of the area occupied by mineral A to the area occupied by all minerals (the total measurement area) is a consistent estimate of the volume percentage of mineral A in the rock."

Minerals

The minerals observed in thin section examination are here described by their diagnostic characteristics and listed in the order of decreasing abundance.

Quartz (Chert) - Chert is defined for this study as a chemically precipitated silica which has been recrystallized to microscopic quartz grains. The grains are colorless in plain light and exhibit undulatory extinction between crossed nicols. The diameter of the average quartz grains is 0.006 mm. but extremes in grain size ranging from 0.003 mm. to 0.3 mm. in diameter were noted. Chert is the major constituent of the "oxide bearing member" and exists in massive to thin layers interbedded with carbonate.

Carbonate - The predominant amount of carbonate is of anhedral grains usually less than 0.6 mm. long and one-half as wide. Under plain light it is cloudy gray to colorless and between crossed nicols a gray brown. The author observed a minor quantity of colorless to high interference order white rhombs in association with fine to medium grained chert. These euhedral grains are up to 0.2 mm. long. Both varieties usually exhibit rhombohedral cleavage lamellae.

Magnetite - Minor amounts of this mineral are in individual opaque octahedrons or dodecahedrons. Most of it however, occurs as subhedral, anhedral and rice-like grains.

Minnesotaite - This hydrous iron silicate appears as radiating bundles of needles or plates, averaging 0.03 mm. long, scattered in the chert layers. It is colorless or may be gray-green to yellowish. Parallel extinction, high birefringence and little pleochroism are distinctive optical properties of minnesotaite. According to Gruner (1944B) minnesotaite varies between considerable limits in the ratio of Fe'' to Fe''' to Mg. This mineral has a talc crystal structure revealed by X rays. Gruner (1944B) assigns the following chemical formula to minnesotaite:

$$(OH)_{11}\ (Fe'', Mg)_{11}\ (Si, Al, Fe''')_{16}\ O_{37}$$

Stilpnomelane - This mineral is abundant in the two "slate" members and appears in minor amount in the "Iron formation". In core pieces it is seen as green to black needles, in crushed core as green-black plates or blades and in thin rock section as blades averaging 0.2 mm. long. It occurs in the chert and carbonate as sheathes and irregular fibers of yellow-green ferrous and yellow-brown ferric forms. Pleochroism of stilpnomelane is distinct, except in places where finely grained crystals are not aligned parallel to each other. In the latter instances it is impossible to distinguish stilpnomelane from the other hydrous iron silicates. It crystallizes as a mica and chlorite unit cell structure. The chemical formula proposed by Gruner (1944A) for stilpnomelane is :

$$(OH)_4\ (Fe'', Mg, Al, Fe''')_{7-8}\ Si_{18}O_{23-24}\ 2\text{-}4\ H_2O$$

Limonite - Limonite is described by Dana (1944) as a cryptocrystalline goethite containing absorbed water. A portion of the staining is probably lepidocrocite, which is dimorphous with limonite. This hydrous ferric mineral is observed as yellow to orange-red colored staining under reflected light and is semi-opaque in plain light.

Hematite (Martite) - The hematite observed is pseudomorphous after magnetite. Han (1957) describes martite as:

> ". . . actually a hematite aggregate, usually containing variable amounts of magnetite and occasionally goethite and pyrite, which is contained within the crystal form of magnetite or pyrite . . ."

Han states further that it is formed by diffusion of oxygen along the fine grained crystal boundaries of the magnetite crystals. Martite is observed as a ruby red colored mineral under reflected light.

Muscovite - Muscovite is present in minute amounts associated with quartz, carbonate and magnetite. It is colorless in thin section with plain light and the grains appear as low relief blades and scales. Muscovite exhibits very little pleochroism, but has marked interference colors of violet, blue, green and red. Optically it has a small 2V and is negative in sign.

Pyrite - This iron sulfide occurs in small irregular grains in the extremely fine grained carbonate bands. Also a very small quantity was seen in the chert layers

Graphite - The author observed minor amounts of minute plates of a black opaque mineral thought to be graphite in the fine grained carbonate layers.

"Upper and Lower Slates"

The upper and lower "slate" members are very similar in mineral content and textural appearance. They both are non-magnetic to only slightly magnetic, usually thin to medium banded and composed of fine to very fine grains. The bands generally consist of alternating light chert layers and extremely fine grained dark carbonate bands. Minor quantities of pyrite and apparently some graphite are associated with the carbonate layers.

Carbonate occurs generally as masses of very small anhedral grains. A relatively large amount of individual carbonate rhombs averaging 0.6 mm in length are located in portions of the "Upper slate". Bradshaw (1956) has noted that the carbonate in bands is anhedral while that occurring in the adjacent chert is euhedral in grain boundaries. This, he explains, is because of its greater power of crystallization and/or recrystallization of the carbonate during diagenesis and lithification.

Quartz, carbonate, stilpnomelane and minnesotaite constitute the major mineral components of both of the "slate" members. Minnesotaite is abundant in the chert as colorless needles and also in minor proportions of light green irregular patches. Blades, sheathes and stringers of stilpnomelane occur in the chert and carbonate groundmasses. An insignificant quantity of magnetite was observed in the "Upper slate".

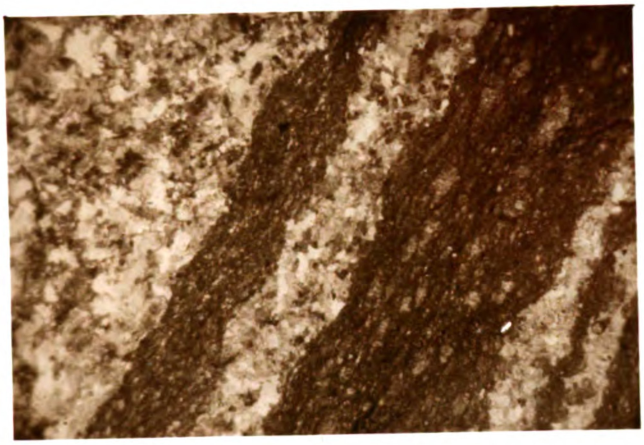


Figure 8. Photomicrograph of Al-#15-22' showing banding of dark carbonate and light chert layers. Plain light, x40 diameters.

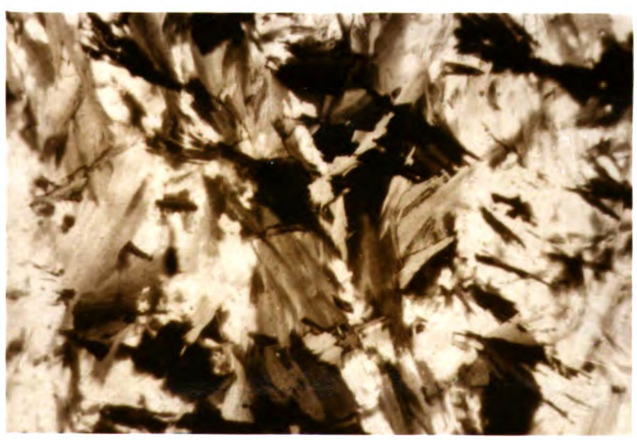


Figure 9. Photomicrograph of Al-#18-140'-150' showing stilpnomelane blades in chert. Plain light, x200 diameters.

Considerable hydration of carbonate to limonite was observed in diamond drill holes Al-#20-38' and Al-#11-60'-65'. This secondary alteration indicates probable recent hydration from the present weathering surface.

"Iron Formation"

The color of the "Iron formation" is light to dark gray but at various places it is altered to a brown-gray, yellow-gray and very frequently to a pink gray. The formation is normally of fine grained material with disseminated larger crystals, plates and stylolitic-like thin wavy bands of Magnetite. Also distinctive yellow-buff patches and bands of carbonate are common. From field evidence it is apparent that magnetic attraction changes with different concentrations of magnetite.

The majority of the rock is composed of chert commonly with an average diameter grain size of 0.006 mm. Carbonate is overwhelmingly of anhedral grains in layers and irregular patches. Interspersed oval to bean shaped granules are composed entirely of carbonate or varying amounts of chert and carbonate. Individual carbonate rhombs are surrounded by fine grained chert and commonly have a poikilitic texture with inclusions of quartz grains. This texture may be due to recrystallization of quartz and carbonate, although an

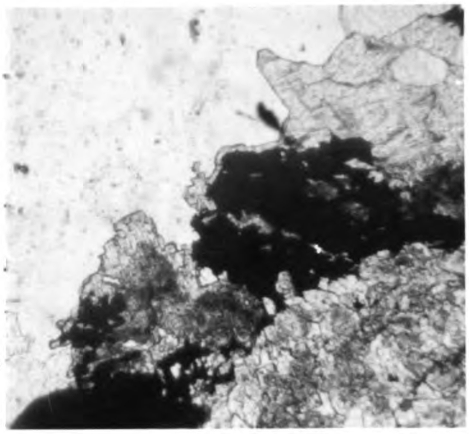


Figure 10. Photomicrograph of Al-#15-6' showing the contact of chert and carbonate layers. Magnetite (black) in carbonate. Plain light, x200 diameters.

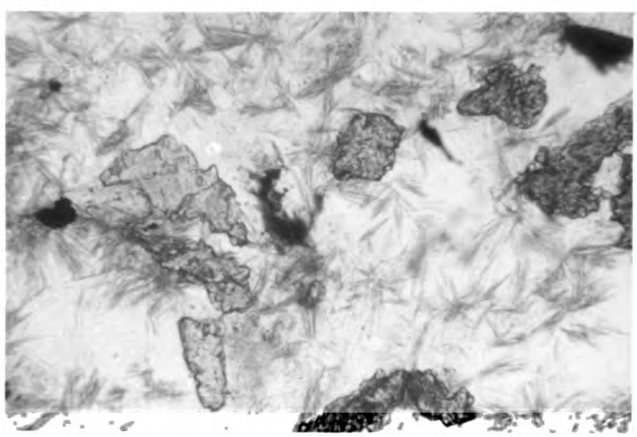


Figure 11. Photomicrograph of Ss-#25-110' showing minnesotaite blades, carbonate, stilpnomelane (dark gray) and magnetite in chert. Plain light, x200 diameters.

interstitial introduction of both can be speculated.

Magnetite exists as irregularly shaped aggregates of anhedral grains and interlocking rice-like grains in distorted fabrics. Magnetite very frequently is observed to partially replace the peripheral portions of the carbonate granules. The substituted parts of the carbonate grains are anhedral to rice-like in shape, which points out an extensive replacement of pre-existing carbonate by magnetite forming what are now predominant textures in some horizons of the "oxide bearing member". A small amount of euhedral grains of magnetite are present.

There is a minor amount of minnesotaite and stilpnomelane in the iron formation compared with the "slate" members. A small quantity of the rice-like grains of magnetite may be pseudomorphous after minnesotaite needles and plates. The author viewed several locations in thin section where stilpnomelane was partially replaced by subhedral to anhedral grains of magnetite.

The muscovite content of the "Iron formation" appears to be confined to occurrences in the Altanel Sheet area. It was observed in four rock thin sections, three of which were at the 100' horizon. Under high magnification muscovite has a clean boundary with the associated chert, carbonate and magnetite. The scales of muscovite are differentiated by their brilliant colors between crossed nicols. Needles of chlorite appear in the muscovite scales. The rounded

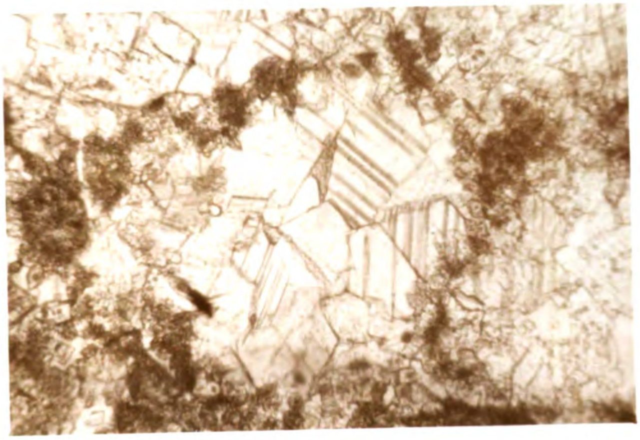


Figure 12. Photomicrograph of Ss-#24-20A showing small anhedral and large rhombs of carbonate. Stained rings are limonite. Plain light, x200 diameters.

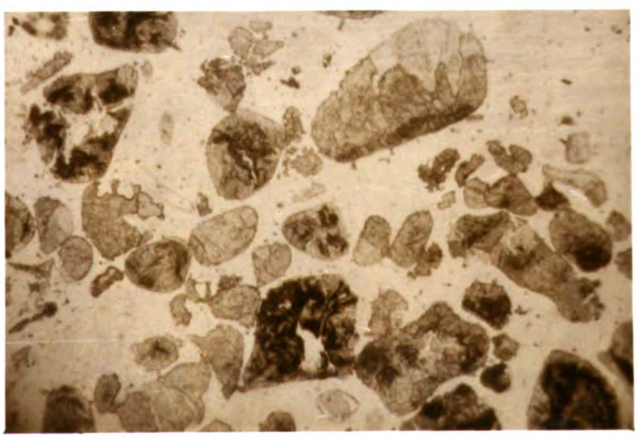


Figure 13. Photomicrograph of Al-#20-38' showing carbonate granules in chert. Staining is limonite. Plain light, x200 diameters.

form of the scales denotes a probable clastic origin.

Incipient hydration shown by yellow to orange-red semi-opaque smears and stains of limonite abound in the carbonate masses. Thin section Ss-#29-4' displays unusual oval rings, probably of limonite, which appear to cut across the equal grained chert when viewed between crossed nicols. The ring-like nature and apparent penetration of these stains may be explained by the fact that a thin section consists of more than on plane. Thus the rings could be above the chert it seems to cut. Also during original formation an iron bearing mineral was collected around granules composed of chert and carbonate. A matrix of grains very similar in size to the chert of the granules were later crystallized in a surrounding groundmass. Hydration of the iron took place at a later time.

Martite is observed as a rim replacement of large magnetite grains, and as pseudomorphs after dust size euhedral magnetite grains.

The magnitude of secondary alteration can be only roughly estimated and this is tabulated in Tables II through X. The amount of hydration and oxidation observed is attributed to shallow burial or exposure to the present land surface.

The preceeding paragraphs are a summary of the textures, mineral composition and relationships of the "Iron formation" that are included in Tables II through X.

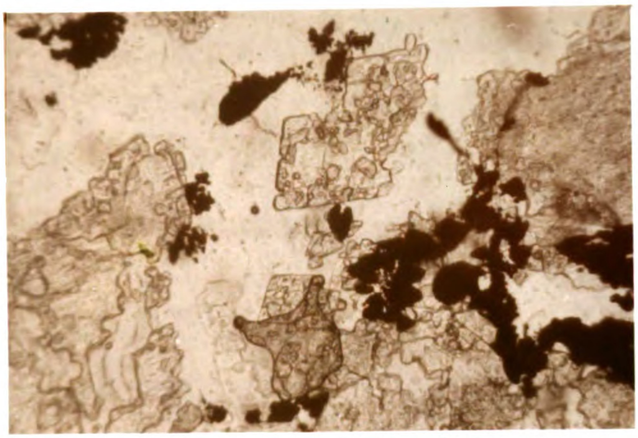


Figure 14. Photomicrograph of Al-#15-137' showing poikilitic texture of the carbonate and magnetite in irregular masses. Plain light, x200 diameters.

Figure 15. Photomicrograph of Ss-#24-125' showing stilpnomelane (medium gray) and carbonate replaced by magnetite all in chert groundmass. Plain light, x200 diameters.

To estimate the mean volume percentages of the mineral constituents, especially the magnetite, the author made a petrographic modal analyses on approximately 50' and 100' horizons of diamond drill core fragments in the "oxide bearing member". The selection of the two horizons was made as randomly as possible to be consistent in finding the unbiased means of minerals of the formation. In each case the sample nearest the selected horizon was analyzed. The estimated volume percentages are listed in Tables II through IV.

An attempt was made to predict the variance of the estimates from the means of the minerals. Thin section Ss-#35-65' was selected to test the reproducibility error, because it was a slide of excellent random spacing of minerals. Theoretically this rock section should mark the upper limit of accuracy in the counting method. The writer determined an average deviation of 1.3 % from the mean of each mineral on three equal length traveres made on separate occasions. An error possibly greater than 1.3 % per mineral would therefor be inherent in counting, if compensating errors are neglected in our measurements. It is difficult to estimate the analytical error due to inconsistent banding and the bladed nature of minerals as compared to the ideal oval shaped grains. The analytical error is then an unkcwn increment added to the counting error and as a result the combined total error could not be estimated. However chert, carbonate

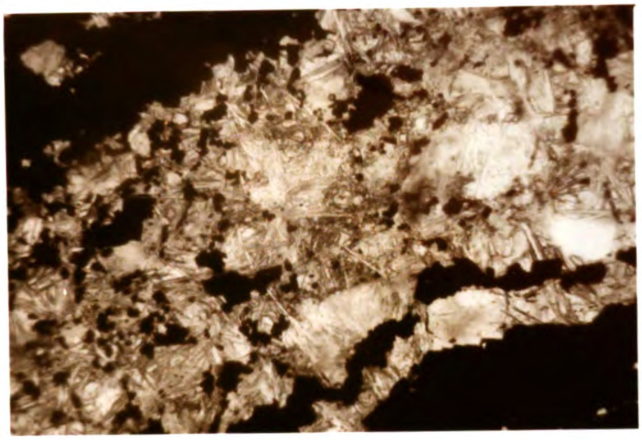


Figure 16. Photomicrograph of Al-#15-162' showing stilpnomelane (medium gray) at border of magnetite bands. Plain light, x200 diameters.

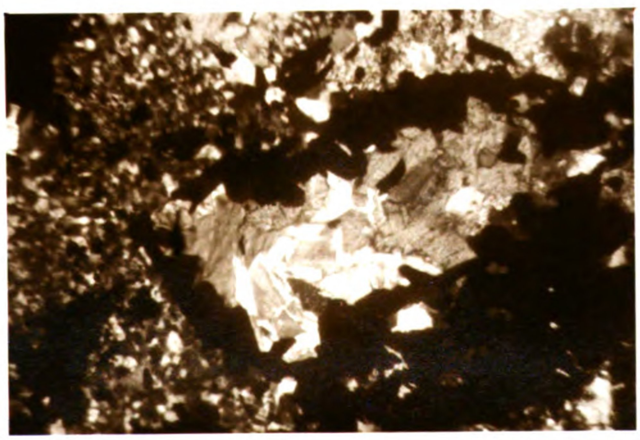


Figure 17. Photomicrograph of Al-#15-57' showing a granule of carbonate (medium gray) and muscovite (light gray) ringed by magnetite in chert matrix. Crossed nicols, x200 diameters.

and magnetite compose the overwhelming percentage of the cores and their respective estimates should have merit.

The validity of estimates of magnetite is proved by comparison of modal analyses computations and metallurgical test results of the same cores. The author assumed the iron content of magnetite to be 72 % and that of carbonate 48 %. The average total iron percentages, in correlation of modal analyses computations with the average listed percentages of 100 mesh metallurgical tests, differed by 2 %. It follows that the magnetite, carbonate and chert volume percentages from modal analyses are valid. The congruence of results indicates the carbonate to be of the variety siderite. Also that the secondary alteration minerals and iron silicates contain a very insignificant amount of the total iron of the formation.

No perceivable mineralogic gradation appears in comparing the two horizons in tracing them from west to east. The computed means of the minerals in the horizons indicate that the upper one has less chert than the 50' horizon. Thus the 100' horizon has a favorable gain in magnetite and silicate minerals. The volume percentages of the major minerals are generally constant throughout the horizons analyzed. In view of this average content a suitable "mill feed" for concentration may be planned by by metallurgists for the "oxide bearing member" of the Temiscamie iron formation.

In detailed examination of slides from cores of the Sandspit and Albanel Sheet areas the writer observed a sequence of development to the present mineralogic content. Stilpnomelane appears in both the chert and carbonate masses. Minnesotaite is observed along the boundaries of the carbonate in the chert. Additional stilpnomelane, carbonate and minor amounts of euhedral grains of magnetite also occur in the chert. This sequence of crystallization from stilpnomelane to the chert probably took place during diagenesis. The author favors Gruner's explanation of the paragenesis of the minerals and thinks it may apply to the Temiscamie iron formation. Gruner (1946) writes:

> "As stilpnomelane is from, let us assume, a colloidal gel, it will take the ions in its neighborhood which are most convenient and of the necessary charge. If it cannot find any more it will stop growing. The leftover gel material, then, may be of the proper composition to form minnesotaite or greenalite, or quartz and siderite, if Co_2 is available in considerable concentration."

The magnetite in the "Iron formation" appears to have more than one generation of development. Euhedral grains in the chert may be of primary origin. However the predominant amount of the magnetite is secondary. With further research a more complete genesis of the magnetite might be determined.

The writer would like to suggest an idea on the formation of magnetite from pre-existing carbonate and stilpnomelane. James (1954) describes a burial environment possessing a lower redox potential than a deposition environment. With less available oxygen, and at the same time the action of the organic material present in the original material, reduction of the iron oxides in the mud takes place as the material is isolated from the oxygenated waters by burial.

CONCLUSIONS

Detailed laboratory examination of core samples revealed certain conclusions relative to the textural relationships and mineralogic content of the "Iron formation".

Macroscopic study pointed out three divisions in the Temiscamie iron formation. The "Upper slate" and "Lower slate" members consist generally of interbedded light cherty and dark extremely fine grained carbonate. Minnesotaite and stilpnomelane are found abundantly in some portions. These two divisions were considered only as a background microscopic study for the "oxide bearing member" and are named "slate" because of their field appearance.

The "Iron formation" is usually gray colored but often tinted pink. Microscopic examination of thin sections indicates irregular patches of anhedral carbonate and bean shaped granules composed of carbonate with minor amounts of chert in an equal-grained chert matrix. A small quantity of minnesotaite and stilpnomelane occurs in the "oxide bearing member" Muscovite in minute amounts was observed in certain horizons.

A sequence of crystallization of the formation from a colloidal gel with initially crystallized stilpnomelane to a finely crystallized chert groundmass is thought to have taken place during diagenesis. Poikilitic textures of rhombs of carbonate, with included quartz grains, indicates a possible post diagenetic recrystallization of carbonate and quartz.

Magnetite is predominantly of secondary origin. The pre-existing carbonate is replaced by an abundance of rice-like and anhedral grains composing irregular aggregates occurring throughout the "Iron formation". Development of the magnetite is thought to have been in a reducing environment.

Petrographic modal analyses made upon thin sections from core fragments at approximately 50' and 100' horizons of the "oxide bearing member". The modal analyses estimation of volume percentages of the major minerals were found to be valid upon comparison with metallurgical test results from the same diamond drill cores. The total iron computations from modal analyses indicated the carbonate to be of the variety siderite. Also an insignificant amount of the total iron of the "Iron formation" is from the combined iron content of limonite, martite and the hydrous iron silicates.

No observable mineralogic gradations from the estimates of modal analyses were delineated along the strike of the "Iron formation". Patches of color variations are not related to essential differences in mineralogic composition. The lack of variance of the chert, carbonate and magnetite minerals suggests that the "oxide bearing member" is uniform and will lend itself to large scale exploitation in the Sandspit and Albanel Sheet areas.

SUGGESTIONS FOR FURTHER STUDY

This detailed examination of drill cores has delineated several problems for further study. Among the most fertile for research are the following.

1. An intensive laboratory investigation of the Mistassini series sediments to determine the paragenesis might prove valuable. Priority should be placed on the study of the "Iron formation" with the determination of the genesis of the magnetite emphasized.

2. A trace element study of the Temiscamie iron formation may suggest important implications on the source material and the environment of deposition of the iron-rich sediments.

3. Identification of the suite of hydrous iron silicates appearing in thin sections may be confirmed by X ray work.

4. Possible effects of structural features upon exploitation of the "oxide bearing member" might possibly be pointed out by careful field mapping.

5. A petrofabric study by plotting c-axes of the quartz grains may provide further evidence for secondary recrystallization of the formations of the region.

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