1

CANADIAN THESES ON MICROFICHE

I.S.B.N.

THESES CANADIENNES SUR MICROFICHE

National Library of Canada
Collections Development Branch

Canadian Theses on
Microfiche Service

Ottawa, Canada
K1A 0N4

Bibliothèque nationale du Canada
Direction du développement des collections

Service des thèses canadiennes
sur microfiche

NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us a poor photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30. Please read the authorization forms which accompany this thesis.

THIS DISSERTATION
HAS BEEN MICROFILMED
EXACTLY AS RECEIVED

AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de mauvaise qualité.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30. Veuillez prendre connaissance des formules d'autorisation qui accompagnent cette thèse.

LA THÈSE A ÉTÉ
MICROFILMÉE TELLE QUE
NOUS L'AVONS REÇUE

National Library
of Canada

Bibliothèque nationale
du Canada

CANADIAN THESES
ON MICROFICHE

THÈSES CANADIENNES
SUR MICROFICHE

60028

147
0-315-12115-7

NAME OF AUTHOR/NOM DE L'AUTEUR Philip L. Reeves

TITLE OF THESIS/TITRE DE LA THÈSE Sedimentary Textures and Structures in the Sokoman Iron
Formation in the Vicinity of Schefferville, Québec

UNIVERSITY/UNIVERSITÉ Carleton

DEGREE FOR WHICH THESIS WAS PRESENTED/
GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE Master of Science

YEAR THIS DEGREE CONFERRED/ANNÉE D'OBTENTION DE CE DEGRÉ 1980

NAME OF SUPERVISOR/NOM DU DIRECTEUR DE THÈSE Dr. J.A. Donaldson

Permission is hereby granted to the NATIONAL LIBRARY OF
CANADA to microfilm this thesis and to lend or sell copies
of the film.

The author reserves other publication rights, and neither the
thesis nor extensive extracts from it may be printed or other-
wise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈ-
QUE NATIONALE DU CANADA de microfilmer cette thèse et
de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la
thèse ni de longs extraits de celle-ci ne doivent être imprimés
ou autrement reproduits sans l'autorisation écrite de l'auteur.

DATED/DATE 23rd Nov 1979 SIGNED/SIGNÉ Philip L. Reeves

PERMANENT ADDRESS/RÉSIDENCE FIXE 150 Williston Drive
Regina, Sask. S4X 1C6

SEDIMENTARY TEXTURES AND STRUCTURES
IN THE SOKOMAN FORMATION IN THE VICINITY
OF SCHEFFERVILLE QUEBEC

by

© PHILIP L. REEVES, BSc.

A thesis submitted to the Faculty of Graduate
Studies and Research in partial fulfilment of
the requirements for the degree of Master of
Science.

Department of Geology
Carleton University
Ottawa, Ontario
September 1979

The undersigned hereby recommend to the Faculty of
Graduate Studies and Research acceptance of this thesis,
submitted by Philip L. Reeves, B Sc., in partial ful-
filment of the requirements for the degree of Master
of Science.

.....
G. B. Skippen, Chairman,
Department of Geology

.....
J. A. Donaldson, Supervisor

ABSTRACT

The Labrador Trough is an extensive belt of lower Proterozoic rocks which forms part of a distinctive structural unit known as the Circum-Ungava Geosyncline. A prominent sedimentary unit within the Trough is the Sokoman Formation, a banded, cherty, Superior-type iron formation which is the largest continuous sedimentary iron deposit in the world. The Sokoman Formation underlies much of the study area, in the western portion of the Labrador Trough, three miles southeast of Schefferville, Quebec.

Extremely variable in character, the Sokoman Formation consists of alternating silica-rich and iron-rich beds. The silica-rich beds are predominantly chert and jasper and the iron-rich beds contain various combinations of hematite, magnetite, goethite, limonite, greenalite, minnesotaite and stilpnomelane. The Sokoman Formation has been divided into three members and seven submembers in the study area.

Granules and oolites are prominent sedimentary structures in the iron formation units. The granules occur predominantly in the upper portion of the Sokoman Formation and are commonly associated with chert exhibiting colloform texture. Oolites and oolite-like forms are present throughout the Sokoman Formation except in the basal submember and are particularly abundant in the Middle Iron Formation Member. The oolites exhibit various degrees of deformation, mainly elongation and flattening, although some are highly distorted.

Recrystallization is common, and therefore few of the oolites exhibit pronounced internal structure. Many oolites contain syneresis cracks and exhibit penecontemporaneous deformation, implying origin from a colloidal siliceous precursor rather than replacement of pre-existing carbonate oolites. The Sokoman granules, oolites and pseudoolites are indicative of chemical and mechanical deposition and diagenesis in shallow-water, predominantly high-energy, environments.

Many of the chert beds contain nucleus bearing spherical structures which appear to be microfossils. Examination of these structures and comparison to synthetically produced quartz spherulites suggest that most can be explained by strictly inorganic processes related to spherulitic crystallization of colloidal precursors. At least some of the microstructures, however, warrant classification as "probably biologic" in origin. Statistical studies of size distributions are needed to test the biogenicity of these microstructures.

The mineralogical and textural similarities of many of the cherty submembers necessitates the use of stratigraphic position in identifying some of the units. Abundant granules, some of which display syneresis cracks and evidence of penecontemporaneous deformation suggest that the Sokoman Formation was at least in part derived from hydroplastic mixtures of gelatinous silica and hydrated iron minerals. Deposition of the iron formation probably occurred in a shallow sea which was subject to periods of turbulence during storms.

ACKNOWLEDGEMENTS

I would like to thank Dr. J. A. Donaldson for his patience, encouragement, and guidance throughout the duration of the project and for his critical reading of the manuscript. Partial support was also provided by Dr. Donaldson through National Research Council of Canada Grant A5536.

My thanks are extended to the Iron Ore Company of Canada (IOC) for permission to work on the project. Special thanks are given to Dr. T. K. Krishnan for his encouragement in the final stages of the project and for reading portions of the manuscript. Many of my colleagues have helped me a great deal through discussions and innumerable acts of kindness during the field work and preparation of the manuscript. I would like to thank in particular Dick Arndt, Graham Cuddy, Bruce Simonson, and Francois Gay. Thanks are also due to Judith Baker of Carleton University for her assistance with the X-ray analyses and interpretations, and to Carol Seel of Regina for typing the final manuscript.

Finally special thanks are extended to my wife Mary for her patience, understanding, and encouragement throughout the duration of the project.

TABLE OF CONTENTS

	Page
ABSTRACT	iii
ACKNOWLEDGEMENTS	v
TABLE OF CONTENTS	vi
LIST OF TABLES	vii
LIST OF ILLUSTRATIONS	viii
1.0 INTRODUCTION	1
1.1 Previous Work	4
1.2 Location and Access	5
2.0 GEOLOGICAL SETTING	7
2.1 Stratigraphy	8
2.2 Structure	17
2.3 General Depositional Environment	19
3.0 GENERAL THEORIES ON THE ORIGIN OF PRECAMBRIAN IRON FORMATIONS	23
4.0 STRATIGRAPHY OF THE SOKOMAN FORMATION	31
4.1 Lower Iron Formation Member	34
4.1.1 Ruth Submember (RF)	34
4.1.2 Lower Iron Formation Submember (LIF)	35
4.2 Middle Iron Formation Member	38
4.2.1 Lower Red Cherty Submember (LRC) ..	38
4.2.2 Pink Grey Cherty Submember (PGC) ..	40
4.2.3 Upper Red Cherty Submember (URC) ..	42
4.3 Upper Iron Formation Member	43
4.3.1 Grey Upper Iron Formation Submember (GUIF)	43
4.3.2 Lean Chert Submember (LC) ..	45
5.0 SEDIMENTARY TEXTURES AND STRUCTURES IN THE IRON FORMATION UNITS	49
5.1 Granules	51
5.2 Oolites and Pseudoolites	64
5.3 Other Sedimentary Textures	89
6.0 POSSIBLE PRECAMBRIAN LIFE FORMS	
6.1 Micro-Problematica	
7.0 CONCLUSIONS	106
SELECTED BIBLIOGRAPHY	108
APPENDIX I	117

LIST OF TABLES

	Page
TABLE 1: TABLE OF FORMATIONS FOR THE SCHEFFERVILLE AREA	9
TABLE 2: SUBDIVISIONS OF THE SOKOMAN FORMATION	16
TABLE 3: TEXTURAL COMPONENTS OF LIMESTONES AND IRON FORMATIONS	50

LIST OF MAPS

MAP 1: REPRESENTATIVE PORTION OF THE 200 SCALE DETAILED MAPPING	120'
MAP 2: COMPOSITE MAP OF THE STUDY AREA ILLUSTRATING LOCATION OF MEASURED SECTIONS AND SAMPLE SITES	In Pocket

LIST OF ILLUSTRATIONS

Figure		Page
1.	Regional location map of the thesis area with schematic representation of the Circum-Ungava Geosyncline	2
2.	Detailed location map of the study area	3
3.	Relation of sedimentary textures to depth and physical energy of depositional environment	21
4.	The five general unit textures of the Sokoman Iron Formation	32
5.	Common iron oxide textures	33
6.	Sample of the basal Ruth submember showing graded bedding	36
7.	Typical shaly facies of Ruth submember illustrating fissility parallel to bedding	36
8.	Typical LIF, illustrating irregular banding caused by chert lenses	39
9.	Typical LRC outcrop showing distinctive jasper bands and lenses	39
10.	View showing area of typical outcrop (PGC) from the thesis area	41
11.	Closeup view of massive facies within the PGC	41
12.	Closeup view of banded facies of the PGC	44
13.	Typical URC outcrop with bright red jasper lenses	44
14.	GUIF outcrop surface showing characteristic pitted weathering	46
15.	Bedding surface of GUIF showing numerous white chert fragments	46
16.	Distinctive pisolitic horizon within the Lean Chert	48
17.	Granules in the LC unit exhibiting a wide range of deformation	54
18.	Closely packed deformed granules in the LC unit	54

Figure	Page
19. Greenalite granules in the green chert facies of the LC unit	56
20. Rosette of stilpnomelane on the end of a greenalite granule, may be indicative of metamorphism	56
21. Closeup of the margin of a greenalite granule showing rim formed by small opaque grains ...	59
22. Syneresis cracks in an opaque granule, subsequently filled with quartz grains	59
23. Granule in the green chert exhibiting brittle fracture	60
24. Granules in chert illustrating compactional deformation <u>in situ</u>	60
25. A fracture in a granule-bearing horizon illustrating the structural homogeneity of the material subsequent to lithification	61
26. Colloform texture in the LC unit	61
27. Granule exhibiting syneresis cracks which have produced surface notching	62
28. Recrystallized magnetite grains outlining a granule	62
29. Process-response model of cherty iron formations. Interpretation of observed features by comparison with Recent Sediments	63
30. Types of allochemical contacts in oolitic limestones	66
31. Schematic representation of the major types of distorted oolites as they appear in thin section	68
32. Well formed oolite in the LC. The nucleus is not well defined now due to recrystallization. The radiating fractures may be due to shrinkage	69
33. Typical pseudoolites in the LC unit showing various degrees of deformation	71
34. Pseudoolites in the PGC showing crude ellipsoidal shape but lack of internal structure .	71

Figure	Page
35. Opaque pseudoolite in LRC with well-developed syneresis cracks	74
36. Pseudoolites and intraclasts in the LRC	74
37. Sketches of remnant oolitic structures in the LRC	75
38. Possible half moon oolite in the LRC	75
39. Sketches of pseudoolites in PGC	77
40. Pseudoolite composed of quartz grains (recrystallized) which is difficult to differentiate from the cement, especially in plane light	77
41. Oolite in PGC that has a granule for a nucleus	78
42. Granule in the end of an elongated pseudoolite in the PGC	78
43. Elongated pseudoolite in the PGC	79
44. Highly desiccated pseudoolite in the PGC	82
45. Pseudoolite in the URC exhibiting extensive magnetite recrystallization	82
46. Fragment of oolite in LC, a product of brittle deformation as outlined in Carozzi's Group 3	83
47. Oolite in LC with relict internal structure, possibly representing an overgrown granule .	83
48. Pseudoolites in LC with two apparent nuclei.	86
49. Pseudoolite in the LC exhibiting remnant colloidal texture	86
50. Remnant colloidal texture in a pseudoolite in the green chert facies of the LC	87
51. Oolite-like form in the green chert facies of the LC consisting of an opaque granule surrounded by chert, and then a layer of micro spheres	87

Figure	Page
52. Deformed pseudoolite with relict internal structure	88
53. Highly deformed and hooked pseudoolite in the green chert facies of the LC	88
54. Unusual iron oxide concretions in the PGC in the central portion of the map area	92
55. Stylolites in the LC unit	93
56. Quartz grains growing along a preferred orientation in desiccation fractures in an opaque band	93
57. Geologic column summarizing the temporal distribution of stromatolites, microbiotas, and fossil-like microstructures now known from sediments of Archean (3760 < 2500 m.y.) and Proterozoic (2500 < 600 m.y.) age	95
58. Hofmann's scale of reliability for evaluating Precambrian remains	96
59. Schematic representation of the cell division process	98
60. Distinctive colloform texture in the LC unit	100
61. Closeup view of the microspheres with the opaque nuclei in the LC unit	100
62. Quartz microspheres in the LC unit	101
63. Quartz spherulites in what appears to be a remnant granule or pseudoolite	103
64. Small microstructures in the chert rims of larger microspheres (possible pseudofossils)	103
65. Possible microfossils within the cherty portion of a group of quartz spherulites...	104
66. Possible degraded algal filament in the chert of the LC unit. Also numerous small microstructures that may be microfossils	104
67. A series of photomicrographs along a healed fracture in the LC illustrating similarities to algal filaments - a pseudofossil	105

1.0 INTRODUCTION

The Sokoman Iron Formation is a prominent unit within the Knob Lake Group of the Kaniapiskau Supergroup, an extensive belt of lower Proterozoic (Aphebian) rocks which is commonly known as the Labrador Geosyncline or Labrador Trough. These rocks form part of a distinctive structural unit described by Dimroth et al (1970) as the Circum-Ungava Geosyncline (Fig. 1). The Sokoman Formation is a banded, cherty, Superior-type iron formation, and ranks among the largest deposits of this type in the world.

This thesis summarizes a study of the Sokoman Formation in an area about three miles southeast of Schefferville, Quebec (Fig. 2). The study was carried out to obtain more detailed information about the Sokoman Formation as an aid to a better understanding of the mode of formation of Precambrian iron formations. An attempt was made to find criteria useful for distinguishing the various stratigraphic submembers of the Sokoman Iron Formation as an aid to future mapping in this area.

Because many of the cherty submembers of the Sokoman Iron Formation are extremely similar in appearance, stratigraphic position commonly has to be used to identify some of the units. The study involved field work and detailed

Figure 1: Regional location map of the thesis area with a schematic representation of the Circum-Ungava Geosyncline(after Klein and Fink, 1976) .

Figure 2 : Detailed location map of the study area.

examination of 59 thin sections from nine stratigraphic sections across the Sokoman Formation, searching particularly for primary sedimentary structures and textures that might prove to be diagnostic for the identification of certain submembers of the Sokoman Formation. However, the field work did not reveal any such diagnostic features. Granular and oolitic or pseudoolitic textures are by far the most abundant characteristics and these occur in most of the submembers. Cross-bedding was observed in several locations, but none of the exposures were good enough to permit reliable measurement of current directions. Due to the scarcity of distinctive megascopic structures and textures, this thesis concentrates mainly on the thin-section petrography of the Sokoman Formation in the study area. Attention is directed especially to the widespread granular, oolitic and pseudoolitic textures, and some possible Precambrian microfossils are described and evaluated. The significance of these distinctive features for the interpretation of depositional environments of the Sokoman Formation is considered in detail.

1.1 Previous Work

Reconnaissance mapping at a scale of 1 inch to 1000 feet was started by the Iron Ore Company of Canada in the early 1950's. This mapping provided accurate differentiation of the iron formation from the surrounding

country rocks. No further work was done in the thesis area until the summer of 1976, when the author supervised a more detailed mapping project for the Iron Ore Company of Canada at a scale of 1 inch to 200 feet. This mapping was done using aerial photographs enlarged from a scale of 1 inch to 400 feet. The main purpose of this mapping was to obtain a more detailed understanding of the extent and nature of the Sokoman Formation in the Schefferville area and to subdivide the unit into sub-members. The work was supplemented by detailed examination of selected stratigraphic sections throughout the map area.

A regional study of the stratigraphy and mineralogy of the Sokoman Formation in the vicinity of Schefferville area was carried out by I. S. Zajac (1974), but no detailed work within the thesis area was included. E. Dimroth and J. Chauvel (1973) studied the general petrography of the Sokoman Formation, but this was predominantly a textural analysis of randomly selected samples. Much additional work has been done on the iron formation in the central Labrador Trough, but none of it pertains specifically to the study area.

1.2 Location and Access

Schefferville is accessible by rail via the 570 kilometer Quebec North Shore and Labrador Railway from Sept-Iles, or by air via Quebecair from Montreal, Quebec,

or Sept-Iles. Iron Ore Aviation, based in Sept-Iles, has daily non-commercial flights to Schefferville during the week. The thesis area is easily reached by road from Schefferville.

2.0 GEOLOGICAL SETTING

The Sokoman Formation is part of a sequence of sedimentary rocks that constitute the miogeosynclinal portion of the Labrador Trough. The Labrador Trough is a northwest-trending belt of Archean strata that extends for more than 960 kilometers from the Grenville Front to the western side of Ungava Bay (Fig. 1). The Labrador Trough has a maximum width of about 100 kilometers in the vicinity of Schefferville, and narrows to the north and south. The western margin of the Trough is defined by the unconformable contact between sediments of the Kaniapiskau Supergroup and the Archean Ashuanipi basement complex. The eastern portion of the Trough consists of basic volcanic and intrusive rocks which to the east "become progressively more metamorphosed and merge almost imperceptibly with older schists and gneisses" (Zajac, 1974, p. 7).

The metamorphic grade within the Labrador Trough is variable. The rocks in the vicinity of Schefferville show little or no metamorphism. Subgreenschist facies is characteristic, and recrystallization within the iron formation is widespread. The metamorphic grade generally increases northward and eastward. Epidote-amphibolite and higher rank metamorphic rocks are abundant in the southern portion of the Labrador Trough which has been affected by the Grenville Orogeny.

Rb-Sr whole-rock age determinations by Fryer (1972) give an approximate age of $1,870 \pm 50$ million years for the primary depositional age of the Sokoman Formation. However, Goldich (1973) suggests that this age may reflect a widespread metamorphic event rather than the age of deposition.

2.1 Stratigraphy

The Schefferville area is underlain entirely by the sediments and minor volcanic and intrusive rocks of the Knob Lake Group, except along the western margin of the Labrador Trough where Archean rocks are exposed. Table I provides a general stratigraphic column for the area. Lithological types will be described as they appear in the unleached state. Leaching and enrichment with iron oxides that give rise to the soft ore deposits alter the lithologies considerably. Table I provides a general stratigraphic column for the area.

The Archean rocks beneath the unconformity along the western margin of the Labrador Trough have been named the Ashuanipi Complex by geologists of the Iron Ore Company of Canada, and have been dated at 2365 to 2505 million years (Lowdon, 1960, 1961). The Ashuanipi Complex includes granitic gneiss, quartz-feldspar gneiss, lit-par-lit gneiss, quartz-feldspar-biotite-garnet gneiss and minor

TABLE 1

TABLE OF FORMATIONS FOR THE SCHEFFERVILLE AREA

(Adapted from Zajac, 1974)

ERA	SUPER-GROUP	GROUP	FORMATION	APPROXIMATE THICKNESS (METERS)	DOMINANT LITHOLOGY
Mesozoic			Redmond		Iron Formation, Rubble, Clay
UNCONFORMITY					
P r o t e r o z o i c					Diabase
		INTRUSIVE CONTACT			
	K a n i a p i s k a u	K n o b L a k e	Menihek	305 +	Shale, Slate
			Sokoman (including Ruth)	85 - 215 +	Iron Formation, Chert, Ferruginous Shale, Slate
			Nimish	0 - 90 +	Greenstone
			Local (?) Unconformity		
			Wishart	20 - 60	Quartzite, Conglomerate, Arkose
			Local Unconformity		
			Fleming	0 - 120	Chert Breccia
			Denault	0 - 185	Dolostone
			Attikamagen	0 - 305 +	Shale, Slate
UNCONFORMITY					
Archean				Gneisses	

granitoid bodies ranging in composition from granite to quartz diorite. Most rocks in this complex appear to be of metasedimentary origin, and the predominant metamorphic grade is granulite facies.

Aphebian rocks of the Kaniapiskau Supergroup rest unconformably on the Archean basement, and in the study area these rocks belong to the Knob Lake Group. Farther north the Seward Formation, which consists predominantly of coarse clastic rocks, constitutes the basal unit of the Knob Lake Group. Although this unit has not been observed in the Schefferville area, it may be present locally.

The Attikamagen Formation, the oldest Proterozoic unit in the thesis area, consists of fissile, fine-grained, greenish grey shale. Commonly cherty, silty or dolomitic (Zajac, 1974, p. 7), this formation ranges in thickness from at least 15 meters to more than 305 meters.

The Denault Formation is a thick bedded, massive dolostone of somewhat variable composition. Chert commonly occurs within the formation as nodules, thin conformable beds, lenses, fracture fillings, and as replacement veinlets (Zajac, 1974, p. 10). Locally the dolostone is highly brecciated, and it is quite variable in thickness, being 60 to 185 meters thick in the main ore zone of the Schefferville area; it thins to the east

and west, and is absent in some areas.

A discontinuous unit of shale above dolostones of the Denault Formation has characteristics similar to the Attikamagen Formation. Harrison (1952) named this unit the Dolly Formation. However, Howell (1954) suggested that the Denault dolostone is a large reef near the top of the Attikamagen and thus lies within, rather than above, the Attikamagen.

The Fleming Formation is a massive breccia consisting predominantly of angular chert fragments in a cherty matrix, with a very minor amount of dolomite and slate fragments. The angular chert fragments commonly display colloform textures. Whereas the mechanism of formation of this breccia and the origin of the chert are not clearly understood, the breccia generally is thought to be intraformational (Zajac, 1974, p. 13).

The Fleming Formation is quite variable in thickness and is absent from the stratigraphic succession in several locations. The unit crops out immediately Southwest of Schefferville, where it has a maximum thickness of 90 to 120 meters (Zajac, 1974, p. 11).

The Wishart Formation occurs throughout the Schefferville area, generally overlying the Fleming Formation. However, along the western margin of the

Labrador Trough, it overlaps the older Aphebian units and rests unconformably on the Archean basement. The Wishart Formation is a light grey, massive to well-bedded, medium- to coarse-grained quartzite, ranging in composition from orthoquartzite to argillaceous quartzite (Zajac, 1974, p. 13). Locally this unit contains arkose, greywacke, siltstone and conglomerate. The basal part of the unit commonly is coarse grained and arkosic, and typically exhibits cross-bedding. These basal beds are overlain by coarse-grained quartzite which generally fines upwards. The upper part of the unit is a coarse-grained feldspathic quartzite in which the feldspar is predominantly microcline. The top of the Wishart Formation is marked by a distinctive layer known as the "Black Chert" horizon, which ranges from 0.5 to 2.0 meters in thickness. The Black Chert consists of massive grey to black cryptocrystalline quartz with sporadic disseminated pyrite and carbonate granules. Locally this unit displays extensive red hematite staining. The thickness of the Wishart Formation ranges from 20 to 60 meters.

The Attikamagen, Denault, Fleming, and Wishart Formations are not iron rich, but locally they show some secondary goethite enrichment. Geologists of the Iron Ore Company generally refer to these formations as "country rock".

Igneous activity occurred east of the thesis area

in the vicinity of Petitsikapau Lake (Fig. 2), where altered basic volcanic and intrusive rocks are collectively designated "Nimish Greenstones" (Zajac, 1974, p. 17). "Volcanism in the Nimish area began during deposition of the Attikamagen shales, continued intermittently, and reached a climax during deposition of the Sokoman Formation. It ended at the time when Menihek sediments began to accumulate" (Zajac, 1974, p. 20). No volcanic or intrusive rocks are present in the study area.

The Ruth Formation is a combination of black, carbonaceous, ferruginous shale and massive, thickly bedded, varicoloured chert. The shaly facies contains disseminated pyrite and commonly is intensely crumpled and highly enriched with red hematite and to a lesser extent limonite and goethite. The basal portion of the shaly facies, where exposed, generally displays well-developed graded bedding. The shaly and cherty facies are interbedded and occur in variable proportions throughout the area. The northwestern portion of the area contains a lateral jaspilitic facies in the upper part of the Ruth Formation that is characterized by the presence of blue hematite, magnetite and jasper. The total thickness of the Ruth Formation in the Schefferville area ranges from 25 to 45 meters.

Harrison (1952) suggested that the Black Chert which marks the top of the Wishart Formation be considered the basal unit of the Ruth Formation because it

has a high content of carbonaceous material, as does the overlying shale.

There is some controversy as to whether the Ruth Formation should be maintained as a distinct formation. Zajac (1974, p. 26) suggested that "the Ruth and Sokoman are in part time equivalent stratigraphic units and are chemically, mineralogically, and genetically related. To maintain them as separate formations is misleading and creates unnecessary problems in correlation and interpretation". The term Ruth Formation was originally introduced to describe the ferruginous black shales above the Wishart Formation, but has gradually come to include most fissile rocks at the base of the iron formation sequence, including some cherty units. This earlier designation of the Ruth Formation is justifiable, because the depositional environment of the ferruginous shales is different from that which typifies the Sokoman Formation, and the shales are more characteristic of Algoma type iron formation. However, the incorporation of silicate and oxide facies material into this unit makes it much more transitional in character, and its overall properties are predominantly like those of the Sokoman Formation. Hence the author concurs with Zajac's suggestion that the Ruth be included as part of the Sokoman Formation. Klein and Fink (1976, p. 460) also agreed with this suggestion. The Ruth shales and cherts have been mapped as iron formation components in the

study but are not important ore forming units. In the remainder of the text they will be referred to as the Ruth submember of the Lower Iron Formation member.

The Sokoman Formation is an iron formation unit and contains the principal ore-forming members of the Labrador Trough. Extremely variable in character, the Sokoman Formation consists of alternating silica-rich and iron-rich beds, typical of Superior-type iron formation as described by Gross (1965). The silica-rich beds are predominantly chert and jasper, and the iron-rich beds contain some combination of hematite, magnetite, goethite, limonite, greenalite, minnesotaite, and stilpnomelane. The Sokoman Formation is generally well bedded and is characterized by granular and oolitic textures. The Sokoman Formation has been divided into three members: the Lower Iron Formation (LIF), the Middle Iron Formation (MIF), and the Upper Iron Formation (UIF). Each of these has been divided into various submembers on the basis of mineralogy, texture, and chert colour. These subdivisions, outlined in Table 2, are subject to lateral facies changes and differ in character from area to area. The Sokoman Formation is 85 to 215 meters thick in the Schefferville area.

The Menihek Formation is composed of black to greenish grey carbonaceous shales which commonly contain disseminated pyrite crystals. The maximum thickness of this

TABLE 2

SUBDIVISIONS OF SOKOMAN FORMATION

FORMATION	MEMBER	SUB-MEMBER	ACRONYM	APPROXIMATE THICKNESS (in meters)	DOMINANT FACIES
S O K O N A N	Upper Iron Formation (UIF)	Magnetic Shales		0 - 6	Oxide-silicate-clastic
		Lean Chert	LC	10 - 25	Chert-carbonate-clastic
		Red Upper Iron Formation	RUIF	0 - 10	Oxide-silicate-clastic
		Lower Lean Chert	LLC	0 - 25	Oxide-silicate
		Grey Upper Iron Formation	GUIF	12 - 24	Carbonate-oxide-silicate
	Middle Iron Formation (MIF)	Upper Red Chert	URC	15 - 27	Oxide
		Brown Chert	BC	0 - 12	Oxide
		Pink Grey Chert	PGC	20 - 35	Oxide
		Lower Red Chert	LRC	8 - 12	Oxide
	Lower Iron Formation (LIF)	Lower Iron Formation; Silicate Carbonate Iron Formation; Lower Grey; Ruth submember	LIF; SCIF; LIF RF	10 - 50	Oxide-silicate-carbonate- Sulphide

unit is in excess of 305 meters.

2.2 Structure

The Schefferville area is characterized by north-west-trending structures that are clearly reflected by the topography and the drainage patterns. All major folds and faults in the area conform to this structural trend.

The degree of structural complexity is variable, but shows a general trend of eastward increase. Along the western margin of the Labrador Trough in the vicinity of the unconformable contact with basement rocks, the Proterozoic sediments are relatively undeformed, forming gently undulating structures with an overall dip of about 5 degrees to the east. The lack of large-scale folding or faulting in this portion of the Labrador Trough may be due to the pinching out of the basal Attikamagen Formation, which generally acts as a zone of decollement (Harrison et al, 1972, p. 22).

Numerous high-angle reverse faults characterize the Schefferville area. All are easterly dipping thrust faults that have vertical displacements ranging from a meter to several hundred meters, generally not in excess of 305 meters (Zajac, 1974, p. 21). Numerous cross faults offset these major faults. The major folds are generally broad, open, and asymmetric; both incompetent and

competent units display drag folds and tight, doubly plunging folds (Zajac, 1974, p. 21).

In the eastern part of the Schefferville area faulting is not as prominent, and the area is characterized by open to tightly closed major folds and drag folds. The abrupt change of deformational style in the east is attributed to the greater thickness of the strata (Harrison et al., 1972, p. 25).

The predominant structural trend of the area indicates that the major orogenic forces acting on this segment of the Labrador Trough were from the northeast. The Hudsonian Orogeny is generally accepted as the main orogenic event which affected this portion of the Labrador Trough (Zajac, 1974, pp. 21, 22). Evidence of pre-Hudsonian structural trends quite distinct from any of the trends within the Labrador Trough have been observed in the Ashuanipi Complex along the western margin of the Trough (Arndt, 1970), suggesting that the Archean basement west of the Trough was virtually unaffected by Hudsonian orogenic forces. The occurrence near Schefferville of brecciated fault-bounded ore pockets containing fossil leaves and wood fragments of Cretaceous age indicates a minor period of post-Hudsonian tectonism (Stubbins et al., 1961).

The structure of the Labrador Trough suggests that extensive crustal shortening has occurred. Harrison (1952, p. 17) suggested shortening of as much as 80%.

but Zajac (1974, p. 22, 23, 24) claimed this amount of crustal shortening to be excessive, and calculated a minimum of 28% and a maximum of 35% shortening for his study area. Zajac's study was based on the examination of detailed sections and was similar to one done by Seguin (1963, p. 44), who calculated an average shortening of 56%.

2.3 General Depositional Environment

The numerous lithological facies in the Sokoman Formation and associated rocks indicate widely varied chemical conditions during deposition. Because the basal units are clastic and the Sokoman Formation contains re-worked chemical precipitates, it appears that this is a marine transgressive sequence over a shoreline with little or no sediment influx. The Wishart Formation is a relatively coarse (locally conglomeratic) unit which contains abundant cross-bedding suggestive of a shallow-water high-energy environment. The Black Chert above the Wishart marks the beginning of chemical sedimentation in the area. A transition from predominantly clastic sedimentation to chemical precipitation of iron and silica is recorded in the Ruth Formation. Well-developed graded bedding has been observed in basal Ruth shales and Zajac (1974, p. 42) suggested that this in association with laminated shales and the absence of cross-bedding, is indicative of deposition by turbidity currents. The cherts in the middle and upper Ruth Formation record a

marked increase of chemical precipitation and are indicative of low sediment availability. The Sokoman Formation is predominantly a reworked chemical precipitate apparently deposited in a somewhat reducing environment. The abundance of granular and oolitic textures suggests that high-energy conditions, above wave base, were prevalent in the depositional basin. The presence of bedded chert in some of the iron formation submembers, however, is indicative of periodic low energy conditions.

Zajac (1974) made an important contribution to the understanding of iron formations in classifying iron formation by depositional environment and pointing out that the composition of iron formation varies as depositional conditions change. He drew facies maps for each submember and described the depositional environment in detail for each of the submembers, of the Sokoman Formation, using sedimentary textures and structures to interpret the physical environment of deposition. Figure 3 illustrates a simplified correlation of the relationship of sedimentary textures to depth and physical energy of the depositional environment. "Deep" refers to depositional areas essentially below wave base; "intermediate" denotes environments intermittently affected by waves and currents; and "shallow" applies to environments dominated by turbulent conditions.

Both physical and chemical controls, as well as some external controls, affected the depositional environment.

Figure 3 : Relation of sedimentary textures to depth and physical energy of depositional environment (from Zajac, 1974 p. 34).

The chief chemical controls are fluctuations in Eh and pH, and the most common sequence of facies changes in the Sokoman Formation, and in other Superior-type iron formations, is carbonate - silicate - oxide. The physical controls are wave and current action which cause intraformational reworking of the sediments, aid the formation of oolites, and influence the Eh - pH balance. External controls which affected the environment during deposition of the Sokoman Formation include tectonic modifications of the Labrador Trough, fluctuations in sea level, and volcanic activity. The basin for deposition of the Sokoman Formation developed at the end of Wishart sedimentation, and went through an initial period of regression followed by a period of transgression, ending in deep-water Menihek sedimentation.

The source of the Wishart Formation was probably the regolith that was present as the sea began to transgress the land. The volcanic center to the east of Schefferville could have acted as a source for the fine clastic material as well as for the iron and silica. There would be little available terrigenous sediment during deposition of the Sokoman Formation because the basement in the area of the Labrador Trough had been previously subjected to a long period of subaerial erosion.

3.0 GENERAL THEORIES ON THE ORIGIN OF PRECAMBRIAN IRON FORMATIONS

Iron formation was defined by James (1954) as "a chemical sediment, typically thin bedded or laminated, containing 15% or more of iron, commonly but not necessarily containing layers of chert". La Berge (1967) amended this definition by stating that the presence of chert interbeds is necessary. He suggested that the non-cherty varieties of sedimentary iron deposits be called ironstones. The prominent alternation of chert and iron minerals has led to widespread use of the general term "banded iron formation". Most authors agree that banded iron formation is restricted to strata of Precambrian age. Cloud (1968) stated that "nothing like it of any thickness or regional extent is found in younger (than Precambrian) rocks." The post-Precambrian ironstones differ in that they are commonly oolitic and are predominantly associated with carbonate rocks. Work by Govett (1966) and by Lepp and Goldich (1964) has demonstrated significant chemical differences between Precambrian iron formations and the younger ironstones. The post-Precambrian ironstones have a higher alumina content, the values for the Precambrian iron formations falling in a very restricted field distinct from all other values. The CaO/MgO ratios for post-Precambrian ironstones are 13 to 14 times greater, and the P_2O_5 and TiO_2 contents are higher, than in Precambrian iron forma-

tions.

Many theories of origin of iron formations have been proposed, but most are highly speculative and inadequately substantiated. However, because of our incomplete understanding of Precambrian environments, speculative theories may be all that can be achieved. Most theories of origin of banded iron formations attempt to account for the following features:

- 1) The environment of deposition
- 2) The prominent banding
- 3) The restriction of these rocks to Precambrian times.

The most widely accepted theories suggested to explain the origin of Precambrian iron formations are briefly summarized below.

Van Hise and Leith (1911) concluded that iron formations are chemical sediments. Recognizing that these rocks contain more iron and silica than most source rocks could possibly provide, they postulated that the sea floor was the environment of deposition, and that the source rocks were large masses of contemporaneous basic igneous rocks. They envisioned direct contribution by magmatic waters released to the sea during emplacement of igneous rocks.

Gruner (1922) suggested a continental source, the iron and silica being weathering products, and rejected the concept of direct contribution of iron and silica

from the magma. He suggested that "vegetation of a low form was abundant, and aided in the rapid decay of the rocks." He postulated the depositional environment to be a lake bottom with the iron and silica being transported in colloidal form and precipitated by algae and bacteria.

Moore and Maynard (1929) also postulated colloidal transportation of iron and silica, but suggested that deposition was achieved by the presence of electrolytes in a lake bottom environment.

Woolnough (1941) proposed a model of chemical precipitation, with the iron and silica being weathering products on a peneplain. He envisioned colloidal precipitation taking place in isolated depressions on the peneplain surface. Such depositional basins would be free from currents and the influx of mechanically derived sediment. He explained the banding as being due to changes in the chemistry of the depositional basin due to seasonal cycles of rainfall.

Sakamoto (1950) envisioned banded iron ores to be "products on an environment of distinct chemical weathering and sedimentation". For his model he visualized "that such an extraordinary environment obtained only in the Pre-Cambrian era and has never been reproduced in later geologic ages." Sakamoto considered the banded iron formations to have been precipitated during a long

period during which the earth's crust cooled to conditions similar to the Paleozoic and later ages. He proposed a mechanism of cyclical sedimentation based on wet and dry seasons. Iron was supplied to the lake (separated from the sea by a shallow barrier) during the wet season as colloids or in true solution, and because the basin was acidic, silica was precipitated. During the arid season the basin became alkaline and colloidal silica was supplied. Iron silicates were formed and as the temperature rose, precipitation of iron carbonates and other compounds was accelerated.

James (1954) suggested a structural rather than a chemical relationship between volcanism and iron formations. He suggested that volcanism was instrumental in forming the shallow, restricted basins required for iron formation deposition. The iron and silica would be derived as a result of deep continental weathering, the precipitation and character of the sediments being controlled by oxidation-reduction conditions in the depositional basin.

Alexandrov (1955) experimentally reconstructed the ideal conditions for leaching iron oxide and silica. He suggested that the distinctive banding of silica and iron minerals has been the result of selective soil weathering in different seasons. Seasonal changes of temperature, precipitation and pH cause the soil to yield silica-rich solutions in the warm season and iron oxide-

rich solutions during the cold season.

Hough (1958) also proposed a model involving the seasonal weathering of iron and silica, but he suggested deposition in lakes exhibiting density stratification with seasonal, convectional overturns providing the necessary changes in chemistry at the site of deposition in the lake bottom. Govett (1966) extended this theory to cover a wider environment because he did not believe iron could be concentrated to any extent in a marine environment. He redefined lacustine environment, as opposed to marine environment, to mean a restricted basin that lies within a single climatic regime where a seasonal stratification could develop in the water (not necessarily fresh water).

Lepp and Goldich (1964) suggested that the Precambrian atmosphere was oxygen deficient, facilitating lateritic weathering and the simultaneous transport of iron, manganese and silica. On the basis of chemical data they suggested that the principal minerals originally deposited were siderite and calcite, the siderite altering to hematite and the calcite being replaced by silica. The iron could have been precipitated directly by biologic agents, or be due to reactions related to photosynthesis.

Eugster (1969) postulated a process for the inorganic formation of bedded cherts by the precipitation of magadiite ($\text{NaSi}_7\text{O}_{13}(\text{OH})_3 \cdot 3\text{H}_2\text{O}$) and the subsequent leaching of sodium by percolating ground waters. He proposed

a model for the deposition of Precambrian iron formations in alkaline lakes by a mechanism of seasonal deposition. This idea was further expanded when Eugster and Chou (1973) suggested the playa-lake complex as a possible depositional environment for some Precambrian banded iron formations. They pointed out that a similar model in a marine environment should be quite feasible and ended by stating that: "Perhaps the most obvious conclusion we have reached is that Precambrian iron formations are diversified rocks and are not likely to fit a single depositional model".

Cloud (1968, 1973) proposed a mechanism whereby ferrous iron acted as an oxygen acceptor, the oxygen being a product of photosynthesis of primitive green plants. Upon oxidation, the relatively insoluble ferric iron would precipitate. Seasonal upwelling or variation in the rate of photosynthesis could account for the banding. With the onset of advanced oxygen-mediating enzymes about 1.8 billion years ago, the role of the ferrous iron diminished, resulting in the scarcity of banded iron formations in younger geologic periods. He proposed a variety of sources for the iron and silica, including leaching from low-lying land masses, volcanic exhalative material, and possible upwelling from accumulations in deep stagnant waters. Garrels, Perry, and MacKenzie (1973) discussed a similar sort of mechanism to account for the origin of Precambrian iron formations and

the fact that their occurrence is restricted to Precambrian rocks.

La Berge (1973) proposed a biologic origin for the Precambrian iron formations. He suggested that the common occurrence of spheroidal structures, their relationship to depositional features, and their similarity to organic forms implies that they are relic microfossils. He postulated that they might be the remains of silica-precipitating organisms (perhaps bacteria or algae) and that at least some of the chert has been biologically precipitated.

Holland (1973) proposed that the oceans were the source of the iron in Precambrian iron formations. He suggested that the inferred rate of influx of iron into these depositional basins could not be accounted for by weathering or volcanic sources. He concluded that the iron is derived from upwellings of deep ocean water, which could easily contain relatively high concentrations of iron.

Dimroth and Kimberley (1976) proposed that the Precambrian atmosphere had abundant oxygen and they suggested that the iron formations are early diagenetic replacements of dominantly aragonitic sediment. They suggested that this mechanism applies to both Precambrian and Phanerozoic iron deposits.

The major problems associated with these models are the source of iron and silica and the environments of deposition. The difficulty with suggesting a weathered land mass as the source is the problem of what became of the residual material, especially the alumina. There generally are not enough aluminous shales associated with Precambrian iron formations to account for all the alumina that should be present. The main drawback with a direct volcanic source is the fact many of the major Precambrian iron formations are separated by unconformities from abundant volcanic rocks. Magmatic waters may have supplied additional iron and silica to the depositional basin. However, the most plausible source for the iron and silica would seem to be sea water.

The diversity within single formations and between iron formation occurrences suggests that a combination of several different factors contributed to their formation. However, the restriction of banded iron formations to the Precambrian suggests some link between the formation of these deposits and the evolution of the primitive earth.

4.0 STRATIGRAPHY OF THE SOKOMAN FORMATION

The Sokoman Formation has been divided into three members and seven submembers in the study area. Recognition of the submembers is quite difficult due to the similarities in mineralogy and primary structures throughout the stratigraphic succession. Textural relationships are therefore the main criteria for differentiating these units when the submembers are compositionally similar. Geologists of the Iron Ore Company developed a system for describing these rocks employing "unit textures" (Figure 4), "iron oxide textures" (Figure 5), and to a lesser extent the overall fabric of the rock (Fink 1972). (Unit texture" describes the relationship between the bedded and massive strata; "iron oxide texture" refers to the modes of distribution of the iron oxides within the strata, generally layered or disseminated. "Fabric", as used herein, refers to any distinctive pattern formed by the orientation of discrete particles in the rock.

The stratigraphic subdivisions used in the dissertation are those employed by the Iron Ore Company of Canada (IOC). To cope with the extensive facies changes that became apparent in regional studies Zajac (1974) described the stratigraphy by subdividing the Sokoman Formation into ten members and describing the facies variations in each member. The stratigraphy in the thesis area is generally similar to that typical of the main ore zone, and descriptions of the submembers

MASSIVE

LAYERED

LAMINATED

SHALY
BEDDED

SHALY

- Massive: consists almost entirely of massive iron formation with zero to 10 per cent (by volume) bedded iron formation.
- Layered: consists mainly of massive iron formation interbedded with about 10 to 40 per cent bedded iron formation.
- Laminated: contains 40 to 60 per cent bedded iron formation with the remainder consisting of massive iron formation.
- Shaly Bedded: contains 60 to 90 per cent bedded iron formation with subordinate amounts of massive iron formation.
- Shaly: consists almost entirely of bedded iron formation with zero to 10 per cent massive iron formation.

Figure 4: The five general unit textures of the Sokoman Iron Formation (After Gunderson 1960).

DISSEMINATED TEXTURES:

LAYERED TEXTURES:

Figure 1. Common iron oxide textures. (Aston & Elder, 1963).

correspond to those of the appropriate corresponding members in Zajac's classification. The marker horizons in the MIF are poorly developed and are discontinuous in the study area. The MIF and LIF are more variable in composition than the corresponding members in the main ore zone.

As previously mentioned, what was formerly called the Ruth Formation is now considered part of the Sokoman Formation and in this thesis the author has designated the Ruth Formation as the lowermost submember of the LIF member (Table 2)

Appendix I contains a representative example of the detailed mapping, a composite map of the area mapped, and generalized stratigraphic columns for the measured sections. Sample locations are recorded on the composite map and the generalized stratigraphic columns. The following section presents a summary of the general features of lithologic units in the study area.

4.1 Lower Iron Formation Member

4.1.1 Ruth Submember (RF)

The Ruth submember predominantly consists of fine-grained, uniform-textured, carbonaceous and ferruginous shales with minor cherty interbeds. Chert locally is more abundant in the upper parts of the Ruth submember. The shale is black to greyish black on fresh surfaces and the weathered surfaces are a distinctive buff colour due to the alteration of thin hematite and minnesotaite

laminae to hydrous iron oxides. The Ruth submember is easily weathered and generally forms topographic lows in the study area.

The basal beds of the Ruth submember are massive and exhibit well-developed graded bedding (Fig. 6). Some coarser fragments at the base of the graded sequence appear to be of volcanic origin. The shale is thinly laminated, exhibits bedding-parallel fissility (Fig. 7) and commonly breaks into shingle-like and pencil-like fragments. The cherty facies generally consists of lenses of red hematite in grey, green, black or white chert. The chert is highly fractured at several localities within the study area. Polygonal jointing patterns were observed at three localities within the thesis area.

The iron content of the Ruth shale is generally less than 10% and commonly is in the form of secondary red hematite and limonite. Some manganese staining was observed. Locally the cherty facies contains beds of massive hard blue hematite. The Ruth submember is non-magnetic and thin sections are generally too fine-grained to allow mineral identification, but X-ray diffraction patterns typically show chlorite and microcline peaks.

4.1.2 Lower Iron Formation Submember (LIF)

The oxide facies lower iron formation submember is the predominant submember of the LIF in the thesis area. Some parts of the study area contain silicate-carbonate

Figure 6: Sample of shale from the basal Ruth submember showing graded bedding. The field of view is 30 mm wide.

Figure 7: Typical shaly facies of Ruth submember illustrating fissility parallel to bedding.

rocks analogous to the silicate carbonate iron formation (SCIF). The LIF is a fine- to medium-grained cherty unit exhibiting layered to laminated texture, with small areas having massive texture. The SCIF-like rocks are fine-grained, shaly textured and exhibit a pronounced bedding parallel fissility. The LIF submember is typically grey to greyish white. The silicate carbonate facies is greenish grey on fresh surfaces and weathered surfaces display a distinctive brownish yellow to reddish orange colour.

Lenses and irregular stringers of white to greenish white chert with distinct boundaries give the unit an overall banded appearance (Fig. 8). Thin sections show that the unit contains minor hematite, goethite, and magnetite (generally occurring in thin bands) and minnesotaite and stilpnomelane (usually in fibrous bundles or sheaves), in a matrix of chert and recrystallized chert. Pseudoolites were observed in most thin sections. X-ray analyses show quartz, magnetite, minnesotaite, and goethite peaks.

The iron generally occurs as disseminated grains or in diffuse layers. The iron silicates occur as disseminated clusters or as thin bands or laminations. Secondary goethite enrichment is common, especially in columnar growths along fracture surfaces. Limonite staining is also prevalent.

4.2 Middle Iron Formation Member

4.2.1 Lower Red Cherty Submember (LRC)

The LRC is a thin oxide facies unit that occurs discontinuously throughout the thesis area. Traditionally in the main ore zone of the Schefferville area the LRC is one of the key marker horizons in the Sokoman Formation. It does make a good marker unit where it occurs in the thesis area due to its distinctive characteristics; however, it is not distinguishable from the rest of the Middle Iron Formation Member in the sections examined. The LRC is a fine- to medium-grained, purplish red, cherty iron formation unit exhibiting layering which gives the unit a banded appearance (Fig. 9).

Lenses and discontinuous layers of dull red jasper with diffuse boundaries give the unit a banded appearance. The matrix consists of fine-grained chert with disseminated magnetite grains and minor iron silicates. The matrix contains some irregular iron oxide bands which are a mixture of magnetite and hematite. Thin sections reveal the presence of numerous minor accessory minerals in the matrix, including clusters of needle-like crocidolite, minnesotaite, sheaths of stilpnomelane, goethite and possibly some siderite. The magnetite grains, although disseminated throughout the specimens, tend to exhibit a trend parallel to the bedding. Quartz, hematite, and goethite peaks were obtained during X-ray analysis, but no iron silicate peaks were detected, probably because these

Figure 8: Typical LIP, illustrating irregular banding caused by chert lenses.

Figure 9: Typical IRC outcrop showing distinctive jasper bands and lenses (has a limited exposure in the thesis area).

minerals make up a low percentage of the rock. This unit contains abundant pseudoolitic forms, which in some cases form a loose open framework that is almost intact. (These structures are discussed in Chapter 5).

The magnetite grains generally exhibit disseminated textures, although in some thin sections they appear to form diffuse layers. Larger masses of iron oxides within the unit exhibit mottled textures and generally consist of hematite and magnetite, although some sections contain mixtures of magnetite and goethite. Most magnetite grains show evidence of recrystallization. Some thin sections show that secondary goethite occurs along small fractures.

4.2.2 Pink Grey Cherty Submember (PGC)

The PGC is a thick, predominantly oxide facies unit that forms the bulk of the Middle Iron Formation Member. This unit is quite variable in the thesis area, ranging from well layered to almost massive. The PGC is fine-grained to aphanitic with local patches exhibiting granular texture. In the thesis area the PGC locally contains some shaly beds. The outcrops are generally greyish on weathered surfaces and reddish grey or whitish grey on fresh surfaces. Figure 10 shows a typical PGC outcrop area.

Much of the PGC outcrop is massive, as illustrated in Figure 11, with disseminated iron oxides and it commonly exhibits granular texture. The PGC locally contains

Figure 10: View showing area of typical outcrop (PGC) from the thesis area.

Figure 11: Closeup view of massive facies within the PGC.

well banded segments, as illustrated in Figure 12, and where this is a predominant feature it usually occurs in the lower part of the unit. Thin sections show that it consists predominantly of chert with patches of recrystallized chert and disseminated iron oxides. Thin bands of magnetite and hematite exhibit a regular sharp layered texture. The magnetite grains are generally disseminated, although in several thin sections they tend to form diffuse layers. Pseudoolitic and granular texture was observed in several thin sections, although many of the pseudoolitic forms are barely distinguishable from the matrix. One thin section displays randomly oriented, fibrous bundles of stilpnomelane associated with the opaques. Some sections contain fibrous minnesotaite rosettes throughout the chert. Locally the unit exhibits minor pock marking. Secondary manganese mineralization was observed along joint and fracture surfaces. Locally the PGC contains a carbonate facies, commonly called Yellow Middle Iron Formation (YMIF). The YMIF is a fine- to medium-grained, greenish purple siliceous unit containing chert, iron silicates and magnetite. It generally exhibits poorly developed banding. Minnesotaite is prevalent in the YMIF, as confirmed by X-ray data. X-ray analyses of the PGC revealed only quartz and goethite peaks.

4.2.3 Upper Red Cherty Submember (URC)

The URC is a thin oxide facies unit that was recog-

A

B

Figure 16: Distinctive horizon in the LC with abundant intraclasts. A. view of outcrop exposure
B. closeup view of a slab cut from one of the samples, exhibiting rip-up intraclasts.

Figure 12: Closeup view of banded facies of the PGC (note heavy lichen cover typical of most outcrop in the area).

Figure 13: Typical URC outcrop with bright red jasper lenses (has very limited exposure in the thesis area).

chert bands or iron oxide laminations. Locally the unit contains disseminated white chert granules and in one location in the central portion of the map area the GUIF contains numerous white chert fragments that have the appearance of porphyroblasts (Fig. 15). Pock marks are common throughout the unit, and the outcrop in some areas has a blotchy appearance due to the replacement of carbonate by limonite and goethite. Thick weathering rinds were observed on some outcrops. Green chert is common in this unit and pink or red chert is rare. Thin section examination revealed a few oolite-like forms, but many of the sections display crude spherical to ellipsoidal forms that are outlined by iron oxide fragments. None of these forms exhibit any internal structure.

The iron oxide content of this unit is low and generally consists of disseminated magnetite. A few outcrops contain minor red hematite and limonite staining occurs throughout the unit.

4.3.2. Lean Chert Submember (LG)

The LC is predominantly a massive silicate facies unit that is extremely variable but easy to recognize because it consists mostly of dense, varicoloured chert and chert fragments. Figure 16 illustrates a distinctive bedded layer within the LC.* The LC outcrops are generally greenish or purplish, but some appear greyish white. In some areas a magnetic shale facies occurs within the LC. The magnetic shale is a fine-grained, greenish

* This bed contains abundant intraclasts, some of which display rinds which may reflect weathering.

Figure 14: GUILF outcrop surface showing characteristic pitted weathering.

Figure 15: Bedding surface of GUILF showing numerous white chert fragments.

black, fissile unit containing disseminated magnetite, and pyrite crystals along fracture surfaces. In some areas this facies is more siliceous and the magnetite occurs as thin laminations as well as being disseminated. Limonite staining is prevalent.

The LC consists of green, purplish, greyish, white chert with minor disseminated iron oxides. Locally it contains bands of dense black cryptocrystalline chert, and green and black chert fragments are common throughout the unit. The LC contains jasper granules in some areas, and locally the unit is highly brecciated. Thin section examination reveals that granules and pseudoolites are common. The green chert consists of greenalite granules in a chert matrix. X-ray analyses show abundant quartz peaks and questionable hematite and barite peaks for the LC, and quartz and minnesotaite peaks and questionable greenalite peaks for the green chert.

The iron oxide content of this unit is insignificant except in the beds of magnetic shale which contain disseminated magnetite and minor secondary red hematite.

A

B

Figure 16: Distinctive horizon in the LC with abundant intraclasts. A. view of outcrop exposure
B. closeup view of a slab cut from one of the samples, exhibiting rip-up intraclasts.

5.0 SEDIMENTARY TEXTURES AND STRUCTURES IN THE IRON FORMATION UNITS

Many different primary textures and structures have been recognized in cherty iron formations, and these features provide direct evidence about their sedimentation, depositional environment, and lithification. Gross (1972) summarized the features common to cherty iron formations and mentioned the lack of documentation of these features in the literature. Granules, oolites, and the alternation of iron-rich and silica-rich laminations are features commonly discussed in the literature.

Iron formation commonly displays a texture in which discrete particles (granules and oolites), like the elements of a clastic rock, show tangential contacts with each other and are separated by a microcrystalline mosaic of cement. The framework of the iron formation is typically within the arenite size range (0.125 mm to 2.0 mm). The cement is generally chert.

Extensive work on the fabric of limestones by Folk (1959, 1962, 1965) has provided a classification which distinguishes between essentially normal chemical precipitates (orthochems) and chemical precipitates that have suffered later transport or the addition of organized aggregates such as sedentary fossils or fecal pellets (allochems). Dimroth (1968) adapted this classification to iron formation sediments as shown in Table 3. Although this appears to be

TABLE 3

TEXTURAL COMPONENTS OF LIMESTONES AND IRON FORMATION

LIMESTONES	IRON FORMATIONS
<u>ORTHOCHEMS</u>	
microcrystalline calcite matrix (micrite)	microcrystalline iron silicate and siderite matrix (femicrite)
calcareous cement (spar)	microcrystalline matrix chert
	microcrystalline cement chert
<u>ALLOCHEMS</u>	
pellets	pellets
intraclasts	intraclasts
oolites	oolites
fossils	shards

(from Dimroth, 1968, Table 1)

a valid system of classifying iron formation textures, the author prefers to retain the term "granule" instead of adopting the term "pellet", which commonly implies a biogenic origin. The term granule has been used extensively in the literature and the implied usage as a textural term rather than a size class is sufficiently obvious to avoid ambiguity.

Apart from the routine bedding structures, the most abundant textural features observed in thin sections of the Sokoman Formation were granules, oolites, pseudoolites and gel structures. Most time was devoted to a detailed study of these features in thin section. These are the features Dimroth would classify as allochems.

The most common orthochemical constituent of the iron formation is clear microcrystalline chert which displays a fine interlocking granular texture. Dimroth (1968) introduced the terminology "matrix chert" and "cement chert" but did not clearly define the difference between the two. Dimroth and Chanvel (1973) suggested that "matrix chert" was probably derived from silica-gel mixed with iron-oxide hydrate and defined "cement chert" as being precipitated in the pore space of a rock after deposition. Some confusion has cropped up in the literature from improper use of the terms chert and quartz when describing the silica component of iron formations. Although the original silica probably deposited was chert, the term "chert" should be restricted to the microcrystalline and cryptocrystalline varieties of silica (ie. less than 0.0625 mm). Where the grain size can be determined without the aid of a microscope (recrystallized or crystallized) an appropriate descriptive term is "mosaic quartz".

5.1 Granules

The term "granule" has several distinct meanings. The term was proposed by Wentworth (1922, pp 380-381) as a size category between sand size and pebble size, having a diameter in the range of 2 to 4 mm. The term has also been used to describe "a little grain or small particle, such as one of a number of the generally round or oval, nonclastic (precipitated), internally structureless grains of glauconite or other iron silicate in iron formation" (AGI Glossary of Geology, 1972, p. 308).

These particles are generally less than 1 mm. in size.

Granules are a distinctive component of Precambrian Superior-type iron formation. The origin and depositional implications of granules are not clearly understood. Possible modes of origin can be classified as: 1) chemical precipitation-accretionary growth 2) gelatinous-colloidal 3) organic and 4) intraclastic. Despite the diversity of possible origins, most evidence indicates that granules have formed in agitated waters at moderate to shallow depths (Zajac, 1974, p. 6). The lack of granule texture in those banded iron formations generally accepted as quiet-water deposits substantiates this conclusion.

Most granules observed by the author are in the LC unit, the uppermost iron formation submember, and particularly in the green chert facies which occurs locally within this unit. A few opaque granules are present in the PGC and LRC, but these are not as distinct as they are randomly scattered amongst the pseudoolites.

The LC granules are composed mainly of chert, quartz and iron oxides. They have a distinctive light brown colour in thin section which is due to minute iron oxide (or

hydroxide) inclusions in the quartz of the granules (Klein and Fink, 1976, p. 471). Some of the chert granules do not possess this brown coloration and generally are indistinguishable from the cementing chert unless viewed in cross-polarized light. The granules exhibit a wide variety of shapes, from spheres to elongated and deformed ellipsoids, in close association (Fig. 17).

Although some spherical to subspherical granules are present, most show some degree of flattening with an average length to width ratio of 3.2 to 1. The average size of the granules is 0.75 by 0.23 mm and the matrix consists of quartz grains with an average size range of 0.04 to 0.12 mm. The grain size in the granules ranges from cryptocrystalline chert up to quartz grains with a maximum size of 0.15 by 0.08 mm. There are some opaque granules and some granules with opaque rims. The granules generally form a very open framework (Fig. 17), although they are locally compacted into a closed framework (Fig. 18).

The green chert facies of the LC unit has a distinctive granule-texture in which most of the granules are composed of greenalite (Fig. 19). Granule-texture is diagnostic of the green chert facies. There are also some chert and minnesotaite granules. The greenalite granules are quite distinctive in thin section because they are dark brown in plane light and appear almost isotropic under crossed Nicols. About one-third of the granules are rounded

Figure 17: Granules in the LC unit exhibiting a wide range of shapes. Field of view is 6.3 mm wide.

Figure 18: Closely packed deformed granules in the LC unit (thin section is twice normal thickness and viewed through oil in plane light). Field of view is 2.2 mm wide.

or subrounded, and the remaining two-thirds display various degrees of elongation (Fig. 19). Although the granules generally display a random orientation, some of the elongated granules show parallel trends (Fig. 19). The average size of the rounded and subrounded granules is 0.29 by 0.34 mm. and that of the elongated granules is 0.22 by 0.58 mm. The grain size of the greenalite granules is essentially cryptocrystalline; Klein (1974, p. 478) reported a grain size of one micron or less in the greenalite he studied. Most of the greenalite granules are monomineralic, but some contain minor patches of quartz and some contain minnesotaite. Klein (1974, p. 458) suggested that greenalite reacts to form stilpnomelane or minnesotaite during metamorphism. Several greenalite granules have fibrous bundles of stilpnomelane on their perimeter, most commonly on the ends of elongated granules (Fig. 20). A few of the granules have thin, fine-grained, dark rims around them (Fig. 21). The material is too fine-grained to identify but probably consists of small grains of opaque minerals.

The opaque granules are most common in the LRC and PGC, although a few occur in the LC. They are generally subrounded to slightly flattened and monomineralic, but some contain inclusions of quartz. They are commonly associated with large oolite-like forms and display linear or radiating fractures interpreted to be syneresis cracks (Fig. 22).

Figure 19: Greenalite granules in the green chert facies of the LC unit.
(plane light). Field of view is 2.4 mm wide.

Figure 20: Rosette of stilpnomelane on the end of a greenalite granule; may be indicative of metamorphism (plane light). Field of view is 0.25 mm wide.

The granules display evidence of deformation ranging from brittle (Fig. 23) to plastic (Fig. 18), implying that the granules were in various states of consolidation when deformed. The predominant form of deformation is stretching, which suggests the responsible mechanism is simply compaction. The brittle deformation illustrated in Figure 23 apparently occurred in situ which indicates that compaction was the most probable mechanism. Apart from the example illustrated in Figure 18, the granules do not show evidence of having undergone extensive compaction during lithification. However, relationships between elongated granules such as that illustrated in Figure 24 indicate at least two episodes of compaction with an intervening period during which the granules were reworked. Such a cycle of events would also explain the random mixture of deformed and undeformed granules. After complete lithification, the granules and the surrounding chert cement acted as a structurally homogenous unit, because during subsequent fracturing the granule boundaries did not act as zones of weakness (Fig. 25). Because the cement does not show any signs of early deformation, all deformation of the granules must have occurred before cementation.

Because of their extremely fine grain size and typical lack of internal structure, the granules provide little direct evidence as to their mode of origin. The largest concentration of granules is in the LC unit, and this unit also commonly exhibits colloform texture (Fig.

26; these colloform textures will be discussed in more detail in Chapter 6). Oehler (1976, p. 1151) suggested that the principal significance of pervasive quartz microspheres in cherts is that they are relict structures indicative of crystallization from viscous colloidal precursors. The probability that the granules originated from a gel-like material is substantiated by the abundance of features resembling syneresis cracks (Fig. 22, 27). The evidence of recrystallization associated with the granules also provides clues as to the depositional history of these sediments. There are two common forms of recrystallization associated with the granules. The first is simply the recrystallization of chert as quartz grains and the second is the recrystallization of large opaque grains which commonly rim the granules (Fig. 28). The fibrous stilpnomelane crystals associated with some of the greenalite granules probably formed as a result of metamorphism rather than diagenesis. Dimroth (1976) proposed a conceptual model to analyse the formative processes in cherty iron formations as a process-response system (solid arrows) based on Walther's (1893-94) concept of comparative lithology, that is on the comparison of ancient and recent rocks (Fig. 29). The same process (observable in the Recent, but not accessible to observation in ancient rocks) will give rise to the same effects, independent of their age. The Sokoman granules appear to reflect a mixture of both chemical and mechanical deposition and diagenesis in a shallow-water, predominantly high-energy environment.

Figure 21: Closeup of the margin of a greenalite granule showing rim formed by small opaque grains. Notice also the small microspheres with dark centers in the surrounding chert (plane light). Field of view is .03 mm wide.

Figure 22: Syneresis cracks in an opaque granule, subsequently filled with quartz grains (plane light). Field of view is 1.1 mm wide.

Figure 23: Granule in the green chert exhibiting brittle fracture (plane light). The field of view is 0.5 mm wide.

Figure 24: Granules in chert illustrating compactional deformation in situ (plane light). The field of view is 1 mm wide.

Figure 25: A fracture in a granule-bearing horizon illustrating the structural homogeneity of the material subsequent to lithification (plane light). Field of view is 5 mm wide.

Figure 26: Colloform texture in the LC unit (plane light). The field of view is 0.5 mm wide.

Figure 27: Granule exhibiting syneresis cracks which have produced surface notching (plane light). The field of view is 0.6 mm wide.

Figure 28: Recrystallized magnetite grains outlining a granule (plane light). The field of view is 0.4 mm wide.

Figure 29: Image-based model of diagenetic formation, interpretation of observed features by comparison with recent sediments (after Misch 1976).

5.2 Oolites and Pseudoolites

By far the most abundant primary components in the iron formation units are oolites and oolite-like forms, which are present in all the submembers except the Ruth. Gross (1965) described granules and oolites as typical of Superior-type iron formations, and he noted that they are remarkable alike in detail wherever examined. The granules and oolites observed in the Sokoman Formation are quite similar to published figures of these features in other Precambrian iron formations such as the Biwabik, Gunflint, Wabush, Temiscamie, Ironwood, and Brockman.

Carozze (1961, p. 262) defined "oolite" as a spherical or subspherical body of any composition, 0.25 to 2 mm in diameter, which displays a nucleus round which at least one concentric layer has been deposited by accretion. Pettijohn (1975, p. 830) stated that they are commonly 0.5 to 1 mm in size. Oolites may appear ellipsoidal or oblate if deformed before solidification, or less commonly they may be deformed into irregular shapes. A distinctive feature of oolites in the Sokoman Formation, and those in many other iron formations, is their siliceous composition, whereas oolites are more commonly calcareous. Some workers have suggested that the oolites in Precambrian iron formations were originally calcareous and that they have been replaced with siliceous material during diagenesis (Kimberley, 1974; Dimroth and Kimberley, 1976).

Carozzi (1961, p. 262) defined pseudoolites as spherical bodies devoid of internal texture. The term is used to describe "oolite-like" features in the iron formation that often contain some vague semblance of internal structure. They are usually larger in size than granules and do not exhibit the close affinity to colloidal chert that the granules generally do. They are in the same size range as oolites and most probably represent recrystallized oolites.

Compaction is primarily a direct function of the weight of overlying sediments; this weight normally induces closer packing, and if increased sufficiently, may lead to crushing and deformation of grains or allochems (Fraser, 1935, p. 945). As compaction increases in oolitic sediments, inter-allochem contacts could be expected to enlarge progressively from tangential, to straight, and finally to concavo-convex or sutured (Fig. 30; Kahle 1966, p. 20).

Carozzi (1961, p. 262) stated that distorted oolites and pseudoolites apparently are rare occurrences in the geological column, and that they display very characteristic features independent of their mineralogical composition. He implied that these features are indicative of the depositional environment of the sediments enclosing them, suggesting that distortions are generated in agitated conditions by reciprocal impacts between oolites and pseudoolites in various stages of diagenetic induration.

Figure 30: Types of allochemical contacts in oolitic limestones (modified from Taylor 1950).

- A - tangential contact
 - B - straight contact
 - C - concavo-convex contact due to plastic deformation
 - D - concavo-convex involving pressure solution
 - E - sutured contact between pellets
 - F - sutured contact between ooids
- (after Kahle 1966)

Distorted oolites and pseudoolites generally occur in a wide variety of shapes, but Carozzi (1961, p. 271-272) suggested that the repetition of similar forms can be assigned to three basic types in which all the observed shapes could be derived by increased stretching and distortion (Fig. 31). His group I includes the most common shapes resulting from the rupture of the outer shell accompanied by an elimination of part of the core. The oolites and pseudoolites in this group exhibit both plastic and brittle deformation, the deformation generally consisting of the pushing in of a flap of the outer shell. Group 2 includes the shapes resulting from the plastic squashing of oolites and pseudoolites into two parts, usually along a great circle. This squashing typically splits open the oolites and in some cases the core is largely eliminated, leaving only distorted and empty outer skins. Group 3 includes those which have been broken along well-defined lines but not distorted, and thus are examples of brittle deformation. The rupture generally appears as a V-shaped crack cutting through the various layers, and a portion of the outer shell may be broken off and preserved in the cement. This process is somewhat analogous to exfoliation.

Although there is an abundance of oolite-like features in the Sokoman Formation, there are very few in the material studied which exhibit the classical oolitic texture of a nucleus surrounded by thin concentric layers resembling growth rings. Figure 32 illustrates a well-formed oolite,

Figure 31: Schematic representation of the major types of distorted oolites as they appear in thin section (after Carozzi, 1961) .

Figure 32: Well-formed oolite in the IC. The nucleus is not well defined now due to recrystallization. The radiating fractures may be due to shrinkage. A. view in plane light B. view under crossed Nicols; note overgrowth of recrystallized quartz C. closeup of the oolitic layers (plane light). Width of the field of view is 0.4 mm in A and B and 0.25 mm in C.

but the nucleus is not well developed and there appears to be some recrystallization in the central portion. The view under crossed Nicols shows an extensive overgrowth of recrystallized chert. Dimroth (1968) shows illustrations of well-formed oolites from the Sokoman Iron Formation in an area north of Schefferville, and Fink (1972) described them along the western margin of the Labrador Trough. Although a few oolites have nuclei surrounded by one or two commonly recrystallized layers, most of the spherical features show no internal structure and are best classified as pseudoolites (Fig. 33). The pseudoolites are generally composed of chert or quartz and/or opaques, the spherical to ellipsoidal shape being poorly defined, especially under crossed Nicols (Fig. 34).

Oolites and pseudoolites occur in cherty horizons throughout the iron formation sequence except in the Ruth, but they are much more abundant in the MIF than the LIF or UIF.

The pseudoolites in the LIF are predominantly composed of quartz and they appear to be recrystallized remnants of oolites. The spherical and ellipsoidal form of many of them is difficult to distinguish in plane light. Their dimensions range from 0.29 to 1.0 mm and they generally show some degree of flattening, with typical length to width ratios of 2:1 to 3:1. They fall into Carozzi's Group I because they generally exhibit slight

Figure 33: Typical pseudoolites in the LC unit showing various degrees of deformation (plane light). The field of view is 4.5 mm wide.

Figure 34: Pseudoolites in the PGC showing crude ellipsoidal shape but lack of internal structure A. view in plane light B. view under crossed Nicols. The width of the field of view is 0.8 mm in A and 1.3 mm in B.

deformation, elongation, and elongation and fracturing. They are composed of quartz or a mixture of quartz and chert and less commonly they have an opaque component. Some of the pseudoolites are rimmed by magnetite grains. The quartz grains range in size from 0.04 x 0.04 mm to 0.04 x 0.08 mm, with sharp boundaries and no evidence of overgrowths or suturing.

The MIF contains many pseudoolites as well as a few crudely developed oolites. The LRC where developed has abundant pseudoolites and some oolites. The pseudoolites are predominantly opaques and exhibit extensive internal fracturing that is interpreted to be syneresis cracks (Fig. 35). Note also the pronounced notching in the rim of the pseudoolite which is indicative of dehydration. The pseudoolites in the LRC tend to be quite large, ranging from 0.5 to 4 mm, and there are some ellipsoidal features up to about 12 mm (Fig. 36). These larger ones are best referred to as intraclasts, using "intraclast" in the sense proposed by Pettijohn (1975, p. 184) in which there are no implications about composition or place of origin. There is a general tendency for these features to parallel the bedding, but some of them are on end, suggesting that these pseudoolites and intraclasts represent a reworked iron oxide bed. There are several roughly spheroidal structures consisting of chert cores surrounded by magnetite crystals which are interpreted to be relict oolites (Fig. 37). One of the oolites in the LRC appears

to be a half moon oolite (Fig. 38) as described by Carozzi (1963). This peculiar feature is interpreted to be the result of solution and collapse within the oolite and can be used as an indicator for tops, when found in place.

The PCC, the iron formation unit that has the greatest stratigraphic thickness in the study area, contains abundant pseudoolites and oolites. Chert or quartz pseudoolites, commonly with opaque rims or magnetite grains on the perimeter, are abundant throughout this unit in the study area (Fig. 39). In some areas where the unit shows extensive recrystallization, the pseudoolites are barely distinguishable from the cementing material (Fig. 40). Some of them have chert cores surrounded by quartz grains and are probably partially recrystallized chert granules or oolites. The oolites have granules as nuclei surrounded by one or two layers of silica and iron oxide (Fig. 41). The nucleus in this figure appears to be a chert granule that has been recrystallized and overgrown with magnetite. There are two layers surrounding the nucleus, the first quartz with minor opaques (possibly recrystallized chert) and the second magnetite. Figure 42 illustrates the occurrence of a granule in the end of an elongate pseudoolite. Extreme flattening at an early stage when the contained granule was more competent than the enveloping pseudoolite seems likely. About two thirds of the oolites and pseudoolites exhibit moderate to extensive flattening and would be in Group I of Carozzi's classifi-

Fig 35: Opaque pseudoolite in LRC with well-developed syneresis cracks. Quartz has crystallized in the syneresis cracks; the chert may be a remnant nucleus. Note also the notching on the exterior of the pseudoolite, another desiccation feature (plane light). Field of view is 2 mm wide.

Figure 36: Pseudoolites and intraclasts in the LRC (plane light). The field of view is 19.5 mm wide.

Figure 37: Sketches of remnant oolitic structures in the LRC.

Figure 38: Possible half moon oolite in the LRC (reflected light). The field of view is 1.6 mm wide.

cation, whereas the remaining one third are rounded to subrounded and show little or no deformation. The average size of these features is 0.33 to 1.0 mm. Figure 43 illustrates an elongated pseudoolite that has been recrystallized. The magnetite grains define the ellipsoidal shape of the feature and the pronounced cracks are probably due to dehydration. Cracks in the pseudoolites and granules interpreted to be syneresis cracks are quite common. Figure 44 illustrates a highly desiccated pseudoolite with extensive syneresis cracks.

The URC has very limited exposure in the study area, but where it does occur it contains pseudoolites consisting predominantly of recrystallized magnetite (Fig. 45). The quartz in this pseudoolite appears to fill syneresis cracks.

The UIF also has abundant spherical features, including oolites and pseudoolites, but it is characterized by having more granules than the MIF. The GUIF does not display well developed ooliths or pseudooliths. A few, crude ellipsoidal forms, roughly outlined by iron oxide grains, appear to be pseudoolites. They are composed of quartz, iron oxides and minor chert; they generally show only minor flattening but exhibit extensive recrystallization.

The LC contains a variety of pseudoolites and oolites

Figure 39: Sketches of pseudoolites in PGC. A Quartz grains with minor opaques on the rim, this type often very indistinct B Quartz grains completely rimmed by opaques (probably recrystallized chert oolites).

Figure 40: Pseudoolite composed of quartz grains (recrystallized) which is very difficult to determine from the cement, especially in plane light (view under crossed Nicols). Field of view is 0.8 mm wide.

Figure 41: Oolite in PGC that has a granule for a nucleus A. view in plane light B. view under crossed Nicols. Width of the field of view is 1.2 mm in A and 1 mm in B.

Figure 42: Granule in the end of an elongated pseudoolite in the PGC (thin section twice normal thickness, viewed under oil in plane light). The field of view is 0.9 mm wide.

A

B

Figure 43: Elongated pseudoolite in the PGC. In plane light (A), the ellipsoidal form is recognized only because of the magnetite and it is much less obvious under crossed Nicols (B). The pronounced cracks through the pseudoolite are probably indicative of dehydration. The field of view is 2.2 mm wide.

associated with its granules, suggesting that both features are indicative of the same type of depositional environment. There are a few well-developed oolites as illustrated in Figure 32, and several fragments of oolites (Fig. 46) which indicate brittle deformation as outlined in Carozzi's Group 3. There are oolites with relics of internal structure that may represent granules that have been overgrown by successive layers (Fig. 47), and some pseudoolites that have two apparent nuclei (Fig. 48). Common types of pseudoolites in the LC are those with relic internal colloidal textures (Fig. 49). This feature also occurs in the green chert facies of the LC (Fig. 50). Although the green chert facies predominantly contains granules, it also has some oolite-like features. Figure 51 illustrates an oolite with an opaque granule as nucleus surrounded by chert and then a layer of microspheres. Figure 52 illustrates a highly deformed pseudoolite with relic internal structure. Note the curved segment breaking off in the lower left corner similar to the fragment in Figure 46. Figure 53 illustrates a deformed and hooked pseudoolite. This hooked form is similar to the deformed pseudoolites in limestone described by Carozzi (1961). It is anomalous to the other pseudoolites observed in the Sokoman Formation as it exhibits a much greater degree of flattening. An alternative explanation might be that it is an unrolled

coating from an oolite but this seems unlikely because it appears to have a continuous outer shell surrounding a recrystallized core.

Carozzi's (1961) studies involved oolitic carbonate rocks (predominantly limestones), and hooked oolites and pseudoolites were a prominent deformational feature in Carozzi's study. He tended to place too much importance on the mechanism of reciprocal impacts between oolites and pseudoolites as being responsible for the deformation and didn't mention the role of compaction in the deformational process. Many of Carozzi's (1961) illustrations show oolites and pseudoolites that have undergone brittle deformation with very little plastic deformation and in these cases his mechanism of reciprocal impacts is probably correct. However, he mentioned the numerous shape variations in his three groups could be derived by increased stretching and distortion, which are processes indicative of compaction.

Kahle (1966) suggested compaction was the responsible mechanism for a wide variety of deformed oolites and the majority of the deformed oolites and pseudoolites in the Sokoman Formation could be explained by this mechanism.

Because of extensive diagenetic alteration, mostly in the form of recrystallization, the oolite-like features do not provide many clues as to their mode of origin. The

Figure 44: Highly desiccated pseudoblite in the PGC. Large fractures interpreted as syneresis cracks (plane light). The field of view is 2.3 mm wide.

Figure 45: Pseudoolite in the URC exhibiting extensive magnetite recrystallization (plane light). The field of view is 2.3 mm wide.

Figure 46: Fragment of oolite in LC, a product of brittle deformation as outlined in Carozzi's Group 3 (thin section twice normal thickness, viewed under oil in plane light). The field of view is 0.5 mm wide.

Figure 47: Oolite in LC with relic internal structure, possibly representing an overgrown granule (plane light). The field of view is 0.5 mm wide.

extensive dehydration features, especially in the opaque oolites and pseudoolites, imply origin from a colloidal precursor and this is further substantiated by the close association with colloform textures. The apparent remnant colloidal textures observed in some of the pseudoolites (Figs. 40, 50) lends further support to this hypothesis. The close association of deformed and undeformed features indicates that deformation took place prior to lithification and that some of the material was partially consolidated and then reworked. This cycle of partial consolidation and subsequent reworking probably occurred several times. The textural features observed are indicative of a subaqueous, shallow-water, predominantly high-energy depositional environment.

Kimberley (1974) and Dimroth and Kimberley (1976) suggested that iron formations were diagenetic replacements of calcareous sediment. The author does not believe that this hypothesis can be used to explain the origin of oolite-like features in the Sokoman Formation. The abundant desiccation features are strong evidence that the oolites, pseudoolites, and granules originated from silica gel or hydroplastic mixtures of gelatinous silica and hydrated iron minerals. Such features would not form in recrystallized quartz, and syneresis cracks in carbonate oolites appear to be unrecorded. Also, if these oolites and pseudoolites were actually replacements of carbonate oolites, there should be some evidence of remnant carbonate in at least a few of the

22
OF / DE

oolites or pseudoolites, if not a few remnant carbonate oolites. Choquette (1955), in his examination of the "State College" siliceous oolite, demonstrated that they were originally calcareous oolites, and he documented evidence of abundant residual carbonate associated with these replaced oolites. The absence of residual carbonate or pseudomorphs of carbonate grains lends further support to a siliceous origin for the Sokoman oolites and pseudoolites. Kahle (1966) noted that pressure solution along the contact between compacted carbonate oolites was common. The lack of evidence of inter-allochthon pressure solution in the Sokoman oolites and pseudoolites lends further support to their primary siliceous origin. Dimroth and Chauvel (1973, p. 112) noted that the textures of limestones and iron formations are similar but not identical. In particular they suggested the occurrence of shrinkage textures, evidence for agglutination and welding of textural elements, formation of ooliths around complex nuclei, and intense syn-sedimentary compaction and deformation of some textural elements, are features not commonly observed in limestone in this form. They concluded that the occurrence of these features are clear indications that the iron formations are not limestones that were replaced by chert and iron compounds after deposition, as had been suggested by Spencer (1971). The Sokoman Formation was deposited at a time when there was little available terrigenous sediment, and it is assumed that the basement in the area of the Labrador Trough had been previously levelled

Figure 48: Pseudoolite, in LC with two apparent nuclei (plane light). The field of view is 0.5 mm wide.

Figure 40: Pseudoolite in the LC exhibiting remnant colloidal texture A. view in plane light B. view under crossed Nicols. The field of view is 0.5 mm wide in both A and B.

Figure 50: Remnant colloidal texture in a pseudoolite in the green chert facies of the LC (plane light). The field of view is 0.6 mm wide.

Figure 51: Oolite-like form in the green chert facies of the LC consisting of an opaque granule surrounded by chert, and then a layer of microspheres (plane light). The field of view is 0.8 mm wide.

Figure 52: Deformed pseudoolite with relic internal structure: Note curved peripheral fragment that is almost completely detached in the lower left corner (plane light). Field of view is 0.6 mm wide.

Figure 53: Highly deformed and hooked pseudoolite in the green chert facies of the LC (plane light). Field of view is 0.8 mm wide.

by along period of subaerial erosion. This type of depositional environment wouldn't be able to provide sufficient organic-rich deltaic sediment to cover the iron formation as required by Kimberley's replacement model.

5.3 Other Sedimentary Textures and Structures

Small (5-40 mm) concretionary structures occur in one of the beds of the PCC in the central portion of the map area (Fig. 54). These concretions are flattened ellipsoids, some of which have a cavity in the center and commonly they show coalescence parallel to bedding. They are extremely uniform in composition, consisting predominantly of iron oxides with minor chert, and do not exhibit any internal structure. The PCC bed in which they occur is a massive cherty facies with no discernable bedding structures. The term "concretion" has been used to describe a variety of objects of diverse character; however all definitions specify a composition different from the host rock, and indicate formation by precipitation from an aqueous solution within the host rock (Pettijohn, 1975). Recognizing the need for better definitions and terminology, Todd (1993) proposed four terms: "accretion", "intercretion", "excretion", and "incretion", based on mode of growth. Accretions grow from the center outward in a regular manner; intercretions are septaria which form by irregular and interstitial growth; excretions grow from the exterior inward; and incursions

are cylindrical forms with a hollow center. Todd's proposal seems not to have been generally followed and usage has recognized difference in form and internal structure applying special names such as "geodes" and "sertaria" to concretionary bodies that display such differences (Pettijohn, 1975).

The presence of central cavities in the concretions suggests an exterior to interior growth, and the pronounced elongation of the concretions suggests early diagenetic formation. The concretions probably formed in response to local fluctuations in the basin chemistry which resulted in the segregation and concentration of the original iron-bearing minerals (possibly iron carbonates).

Sparse stylolites in the LC unit (Fig. 55) are marked by deposits of insoluble materials, recording intrastratal solution after lithification.

Some iron-rich beds approximately 2 mm wide are broken into segments, and the gaps, which are 0.5 to 1 mm wide, are filled with crenulated, elongated quartz grains (Fig. 56). The gaps probably formed as a result desiccation, and the quartz, which shows a preferred orientation, probably was introduced into the gaps soon after formation.

Scour-and-fill structures are quite common and occur predominantly in the MIF and LIF. Minor small-scale synsedimentary folding was observed in several thin sections of Middle Iron Formation Member and Lower Iron Formation Member.

A

B

Figure 54: Unusual iron oxide concretions in the PGC in the central portion of the map area. A. view of the outcrop surface illustrating the frequency of the feature. B. closeup view of the concretions showing their 3-dimensional nature.

Figure 55: Stylolites in the LC unit (thin section is twice normal thickness, viewed through oil in plane light). The field of view is 2 mm wide.

Figure 56: Quartz grains growing along a preferred orientation in desiccation fractures in an opaque band (crossed Nicols). The field of view is 2 mm wide.

6.0 POSSIBLE PRECAMBRIAN LIFE FORMS

For more than a century the occurrence of fossils in rocks older than the Cambrian has been a fascinating yet frustrating topic. Fascinating from the point of view that theories on the origin of life suggest that some sort of life forms should have existed during this time yet frustrating because the subsequent history most of these rocks have undergone minimizes the chances of finding preserved evidence of organisms.

The most common preserved Precambrian life forms are stromatolites and, according to research done during the past several years, microfossils are also abundant in Precambrian sediments. However evidence for the existence of remains of higher life forms is rare and generally is confined to the very latest portion of the Precambrian. The first occurrence of abundant stromatolites corresponds roughly to the Proterozoic - Archean boundary (at about 2500 m.y.) and these features are quite common throughout the Proterozoic record. Evidence of Archean life is much more speculative, and generally is restricted to rod-shaped bacterium-like bodies, filamentous thread-like structures and coccoidal, unicell-like microstructures (Schopf, 1975). Figure 57 summarizes the temporal distribution of documented evidence of possible Precambrian life forms.

Figure 57: Geologic column summarizing the temporal distribution of stromatolites, microbiotas, and fossil-like microstructures now known from sediments of Archean ($3760 < 2500$ m.y.) and Proterozoic ($2500 < 600$ m.y.) age (after Schopf 1975)

Many previous reports of new finds of Precambrian fossils have later been proven either to be not fossils, or not of Precambrian age, so one must be extremely wary when dealing with such data. The problem of the age of the strata can be verified by radiometric dating, but the problem of whether a structure is of biologic origin is much more difficult to resolve. The lack of hard parts in Precambrian fossils and the similarity of their simple morphologies to various inorganic structures further complicates this matter. Hofmann (1971)

26

suggested grouping Precambrian remains into fossils, problematica and pseudofossils depending on how convincing the evidence was, and he set up the grading scale illustrated in Figure 58. The two end members represent definitive classifications, while the intervening groups are structures whose origin is undecided for a variety of reasons. Assignment of a feature to such an arbitrary scale is subjective and reliability (validity?) depends on the experience of the investigator. Fossils are those structures furnishing undoubted evidence of organic origin, while pseudofossils are objects that have a deceptive resemblance to biogenic structures, but are of inorganic origin (Hofmann, 1971, p. 2). Another logical division to make in such a scheme is to consider larger scale or "macro" features as opposed to microscopic or "micro" features.

The author observed no macrofossils or macro-pseudofossils in the study area. However, macrofossils have been reported in the Sokoman Formation in the vicinity of Schefferville along the western edge of the Trough. Fink (1972, p. 106-110) described stromatolites observed in the LC submember and Zajac (1974, p. 93) documented the presence of algal (?) structures on the upper surfaces of beds of his member VIII.

Figure 58: Hofmann's Scale of Reliability For Evaluating Precambrian Remains

6.1 Micro-Problematika

Numerous microfossils and possible microfossils in Precambrian cherts, many associated with iron formations, have been documented by various workers in the field, notably Schopf, Barghoorn and Tyler, Hofmann, and Cloud. Their reported occurrences are generally spherical bodies, usually with some sort of nucleus, or long filament-like structures, and are interpreted to be blue-green algae.

The generally accepted criteria for living organisms are that they: 1) show growth, 2) are capable of reproduction, 3) show response to stimulæ. Evidence of these criteria is generally hard to find, but there is documentation of spherical structures that appear to exhibit simple cell division (Hofmann, 1976, Plate 6; Golubic and Hofmann, 1976, Plates 1 & 2; Schopf and Blacic, 1971, Plate 111). Figure 59 is a diagrammatic representation of the cell division process. The most common method of evaluating possible microfossils is by comparing them to modern day analogues.

As mentioned in Chapter 5, patches in the LC exhibit a very distinctive colloform texture (Fig. 60). When viewed close up (Fig. 61), this material is composed of microspheres of chert, many of them with opaque nuclei in their centers. These features are somewhat similar to large globular microfossils described by Hofmann (1976;

Figure 59: Schematic representation of the cell division process (after Golubic and Hofmann, 1976).

Plate 9) and LaBerge (1973, Figs. 3, 4, 5, 6). They also resemble synthetic spherulites which contain nuclei of organic matter as described by Oehler (1976, Fig. 5 C). Oehler (1976) produced synthetic quartz spherulites in the laboratory which formed directly from silicagel. The quartz crystallized primarily in the form of radially fibrous chalcedonic spherulites averaging 20 μ in diameter. The quartz microspheres synthesized in these experiments have all the characteristics common to quartz microspheres in natural cherts (Oehler; 1976, Fig. 9). Figure 62 illustrates microspheres in the LC in the 15 μ and 30 μ size range. The large size of these microspheres and their similarity to both the natural and synthetic quartz spherulites led the author to conclude that they probably are abiogenic quartz spherulites indicative of crystallization from a colloidal precursor, number 2 on Hofmann's scale. John Oehler (personal communication) agreed with this conclusion after looking at some of my photos and thin sections. The occurrence of similar microstructures in what appears to be the remnants of granules or pseudoolites further supports the theory of a non-biogenic origin for these structures (Fig. 63).

Some of the thin sections contain small spherical features without the dominant dark centers. Oehler (personal communication) suggested these may be primitive algal cells, but they are too poorly preserved to permit any judgements concerning taxonomic affinities. He observed

Figure 60: Distinctive colloform texture in the IC unit (plane light). The field of view is 1.6 mm wide.

Figure 61: Close up view of the microspheres with the opaque nuclei in the IC unit (plane light). The field of view is 0.2 mm wide.

A

B

Figure 62: Quartz microspheres in the LC unit.
A) 15 μ diameter structures (plane light).
B) 30 μ diameter structures (plane light);
note the lack of opaque nuclei in these
microspheres. The width of the field of
view is 280 μ in A and 375 μ in B.

similar structures in LaBerge's thin sections of Hamersley iron formation chert, and suggested they are the only structures from the Hamersley cherts that he would regard as possible fossils, number 4 on Hofmann's scale. The major problem with these features in the Sokoman Formation is that in many areas they seem to grade into the quartz microspheres with dark centers, suggesting they have a similar origin.

A close-up view of one of the quartz spherulites reveals numerous small microstructures within the chert rim of the spherulite (Fig. 64). Detailed examination of other cherts throughout the area revealed similar features (Figs. 65, 66) which may be microfossils, possibly cyanophytes. These features would be 3 or 4 on Hofmann's scale.

The other type of fossil common to Precambrian iron formation cherts is algal Filaments (Barghoorn and Tyler, 1965, Figs. 3, 4; Cloud and Hagen, 1965, Figs. 1, 3, 4, 8, 9, 10, 11, 12, 13; Hofmann, 1971, Plates 105, 106, 107, 108, 109). Figure 66 illustrates a feature that may be a degraded algal filament in the LC. Figure 67 is a series of photomicrographs along a healed fracture in the chert, illustrating the similarity of this feature to possible algal filaments. Such a feature is called a pseudo-fossil in Hofmann's (1971) classification (number 1).

Figure 63: Quartz spherulites in what appears to be a
rearranged granular or pseudotachite (plate 11, 14).
The field of view is 0.7 mm wide.

Figure 64: Shell microstructures in the chert veins of
limestone (plate 11, 14). The field of view is 0.2 mm
wide.

Figure 65: Possible microfossils within the cherty portion of a group of quartz spherulites (plane light). The field of view is 0.1 mm wide.

Figure 66: Possible degraded algal filament in the chert of the IG unit. Also numerous small microstructures that may be microfossils (plane light). The field of view is 0.2 mm wide.

Figure 12: A series of photomicrographs of a specimen, in the 100X magnification, showing the granular texture of the material. The width of the field of view is 0.4 mm in A and B and 0.7 in C.

7.0 CONCLUSIONS

Granular and oolitic textures are distinctive features of the Sokoman Formation. Granules are predominant in the Lean Chert Submember of the Upper Iron Formation and oolites predominate in the Middle Iron Formation. The Lower Iron Formation and the Grey Upper Iron Formation Submember of the Upper Iron Formation contain only indistinct pseudoolites. It would thus appear that textural relationships can be used in conjunction with stratigraphic position to differentiate submembers of the Sokoman Formation.

Many of the granules and oolites exhibit evidence of one or more episodes of penecontemporaneous compaction and deformation. The fact that there are few broken granules and oolites suggests they underwent little transport.

The results of this study indicate that the proportion of granules to oolites in each submember, the shape, size, and sorting of granules and oolites within beds and in groups of beds offer promise for correlation.

The widespread occurrence of granules showing syneresis cracks and penecontemporaneous deformation indicates that the Sokoman Formation was probably derived, at least in part, from hydroplastic mixtures of gelatinous silica and hydrated iron minerals, rather than as replacement of carbonates as suggested by Kimberley (1974) and Dimroth and Kimberley (1976). The lack of relic carbonate in the oolites and granules supports this view.

The oolites and reworked granules indicate high-energy, turbulent conditions, whereas the bedded cherts are indicative of periods of low-energy, quiet-water conditions. Textures

indicate that both mechanical and chemical processes played important roles during diagenesis of the iron formation units. The rocks are chemical precipitates and the most favourable depositional environment is a continental shelf area with an offshore barrier. The most probable source of the iron and silica is the seawater (possibly enriched by volcanic emanations).

The study of possible Precambrian microfossils in the Sokoman Formation revealed that the cherty beds contain numerous microspheres with opaque nuclei. Clusters of microspheres with large opaque nuclei resemble Oehler's (1976) synthetic spherulites and are probably inorganic in origin. However, some of the smaller microspheres fall in the realm of problematica. The larger (30 μ) microspheres with indistinct centers bear some resemblance to primitive cells and quite possibly are of biologic origin.

The author recommends that further study of these features is warranted to determine if any of them can be classified as Precambrian microfossils. The study should involve population analyses of similar microstructures and evaluations of their lateral and vertical distribution in the stratigraphic section. The features observed should be compared to synthetically produced inorganic and organic microstructures. The opaque centers of the microstructures could also be analyzed for possible organic content. Because recrystallization is extensive throughout the study area, unaltered cherts from the western margin of the Labrador Trough probably would provide better samples to pursue such studies.

SELECTED BIBLIOGRAPHY

- Adeleye, D. R.
 1973: Origin of ironstones, an example from the Middle Niger Valley, Nigeria; J. Sediment. Petrol., v. 43, p. 709-727
- 1975: Derivation of fragmentary oolites and pisolites from desiccation cracks; J. Sediment. Petrol., v. 45, p. 794-798
- Alexandrov, E. A.
 1955: Contribution to studies of origin of Precambrian banded iron ores; Econ. Geol., v. 50, p. 459-468
- 1973: The Precambrian banded iron formations of the Soviet Union; Econ. Geol., v. 68, p. 1035-1062
- Arndt, R. E.
 1970: Mineralogy and petrology of a diabase dyke and adjacent Sokoman Iron Formation Howells River Area, Labrador; unpublished MSc. thesis, University of Vermont
- Ayres, D. E.
 1972: Genesis of iron-bearing minerals in banded iron formation mesobands in the Dales Gorge Member, Hamersley Group, Western Australia; Econ. Geol., v. 67, p. 1214-1233
- Barghoorn, E. S., and Schopf, J. W.
 1965: Microorganisms from the late Precambrian of central Australia; Science (AAAS), v. 150, p. 337-339
- Barghoorn, E. S., and Tyler, A. S.
 1965: Microorganisms from the Gunflint Chert; Science (AAAS), v. 147, p. 563-577
- Berner, R. A.
 1971 a: Formation and alteration of silica and clay minerals; Principles of Chemical Sedimentology, McGraw Hill Inc., p. 158-191
- 1971 b: Diagenesis of Iron Minerals; Principles of Chemical Sedimentology, McGraw Hill Inc., p. 192-209
- Button, A.
 1976: Transvaal and Hamersley basins - review of basin development and mineral deposits; Minerals Sci. Eng., v. 8, p. 262-293

Carozzi, A. V.

1961: Distorted Oolites and pseudoolites; J. Sediment. Petrol., v. 31, p. 262-274

1963: Half-moon oolites; J. Sediment. Petrol., v. 33, p. 633-645

Chanda, S. K., Bhattacharyya, A. and Sarkar, S.

~~1977~~: Deformation of ooids by compaction in the Precambrian Bhandar Limestone, India: implications for lithification; Geol. Soc. Am. Bull., v. 88, p. 1577-1585

Chauvel, J. J., and Dimroth, E.

1974: Facies types and depositional environment of the Sokoman Iron Formation, central Labrador Trough, Quebec, Canada; J. Sediment. Petrol., v. 44, p. 299-327

Choquette, P. W.

1955: A petrographic study of the "State College" siliceous oolite; J. Geol., v. 63, p. 337-347

Cloud, P.

1965: Significance of the Gunflint (Precambrian) microflora; Science (AAAS), v. 148, p. 27-35

1968: Atmospheric and hydrospheric evolution of the primitive earth; Science (AAAS), v. 160, p. 729-736

1973: Paleoecological significances of the banded iron formation; Econ. Geol., v. 68, p. 1135-1143

Cloud, P. E., and Hagen, H.

1965: Electron microscopy of the Gunflint microflora: preliminary results; Proceedings of the National Academy of Sciences, v. 54, p. 1-7

Dimroth, E.

1968 a: Sedimentary textures, diagenesis, and sedimentary environment of certain Precambrian ironstones; N. Jb. Geol. Palaont. Abh., v. 130, p. 247-274

1968 b: The evolution of the central segment of the Labrador Geosyncline, part I: stratigraphy, facies, and paleogeography; N. Jb. Geol. Palaont. Abh., v. 132, p. 22-54

1970: Evolution of the Labrador Geosyncline; Geol. Soc. Am. Bull., v. 81, p. 2717-2742

1975: Paleo-environment of iron-rich sedimentary rocks; Geol. Rundschau, v. 64, p. 751-767

- 1976: Aspects of the sedimentary petrology of cherty iron-formation; in Handbook of Strata-Bound and Stratiform Ore Deposits, ed. K. H. Wolf, v. 7, p. 203-254
- 1977: Facies models - 6 diagenetic facies of iron formation; Geoscience Canada, v. 4, p. 83-88
- Dimroth, E., Baragar, W. R. A., Bergeron, R., and Jackson, G. D.
1970: The filling of the Circum-Ungava Geosyncline; in Symposium on Basins and Geosynclines of the Canadian Shield ed. A. J. Baer; Geol. Surv. Can., Paper 70-40, p. 45-142
- Dimroth, E. and Chauvel, J. J.
1973: Petrography of the Sokoman Iron Formation in part of the central Labrador Trough, Quebec, Canada; Geol. Soc. Am. Bull., v. 84, p. 111-134
- Dimroth, E. and Kimberley, M. M.
1976: Precambrian atmospheric oxygen: evidence in the sedimentary distributions of carbon, sulfur, uranium and iron; Can. J. Earth Sci., v. 13, p. 1161-1185
- Donovan, R. N. and Foster, R. J.
1972: Subaqueous shrinkage cracks from the Caithness Flagstone Series (Middle Devonian) of Northeast Scotland; J. Sediment. Petrol., v. 42, p. 309-317
- Eugster, H. P.
1969: Inorganic bedded cherts from the Magadi area, Kenya; Contrib. Mineral. Petrol., v. 22, p. 1-31
- Eugster, H. P. and Chou I-Ming
1973: The depositional environments of Precambrian banded iron-formations; Econ. Geol., v. 68, p. 1144-1168
- Fink, R. P.
1972: Summary of development work on the Howells River project with special reference to the geology of the iron formation; internal report, Iron Ore Company of Canada
- Floran, R. J. and Papike, J. J.
1975: Petrology of the low-grade rocks of the Gunflint Iron-Formation, Ontario-Minnesota; Geol. Soc. Am. Bull., v. 86, p. 1169-1190
- Folk, R. L.
1959: Practical petrographical classification of limestones; Am. Assoc. Pet. Geol., Bull., v. 43, p. 1-38

- 1962: Spectral subdivision of limestone types; in Classification of Carbonate Rocks; Am. Assoc. Pet. Geol., Mem. 1, p. 62-84
- 1965: Some aspects of recrystallization in ancient limestones; Soc. Econ. Paleontol. Mineral. Special Publication 13, p. 14-48
- 1968: Petrology of Sedimentary Rocks, Hemphill's Bookstore Austin, Texas
- Folk, R. L. and Weaver, C. E.
1952: A study of the texture and composition of chert; Am. J. Sci., v. 250, p. 498-510
- Fraser, H. J.
1935: Experimental study of the porosity and permeability of clastic sediments; J. Geol., v. 43, p. 910-1010
- Fryer, B. J.
1972: Age determinations in the Circum-Ungava Geosyncline and the evolution of Precambrian banded iron-formation; Can. J. Earth Sci., v. 9, p. 652-663
- Garrels, R. M., Perry, E. A., Jr., and MacKenzie, F. T.
1973: Genesis of Precambrian iron-formations and the development of atmospheric oxygen; Econ. Geol., v. 68, p. 1173-1179
- Goldich, S. S.
1973: Ages of Precambrian banded iron-formations, Econ. Geol., v. 68, p. 1126-1134
- Goodwin, A. M.
1956: Facies relations in the Gunflint Iron Formation; Econ. Geol., v. 51, p. 565-595
- Golubic, S. and Hofmann, H. J.
1976: Comparison of Holocene and Mid-Precambrian Entophysalidaceae (Cyanophyta) in stromatolitic algal mats; cell division and degradation; J. Paleontol., v. 50, p. 1074-1082
- Govett, G. J. S.
1966: Origin of banded iron formations; Geol. Soc. Am. Bull., v. 77, p. 1191-1212
- Gross, G. A.
1959: A classification for iron deposits in Canada; Can. Min. J., Oct. 1959, p. 87-91

- Geology of iron deposits in Canada; Geol. Surv. Can., Econ. Geol. Rep. 22,
 1965: Vol. I: General geology and evaluation of iron deposits
 1967 Vol. II Iron deposits, Appalachian and Grenville regions
 1968 Vol. III Iron ranges of the Labrador geosyncline
 1972: Primary features in cherty iron-formations; Sediment. Geol., v. 7, p. 241-261
- Gross, G. A. et al
 1972: Iron ranges of Labrador and northern Quebec; 24th Int. Geol. Congr. Guideb. A55
- Grubb, P. L. C.
 1971: Silicates and their paragenesis in the Brockman Iron Formation of Wittenoom Gorge, Western Australia; Econ. Geol., v. 66, p. 281-292
- Gruner, J. W.
 1922: Origin of sedimentary iron formations; Econ. Geol., v. 17, p. 408-460
- Gundersen, J. N.
 1960: Lithologic classification of taconite from the type locality; Econ. Geol., v. 55, p. 563-573
- Harrison, J. M.
 1952: The Quebec-Labrador iron belt, Quebec and Newfoundland; Geol. Surv. Can., Paper 52-20
- Harrison, J. M., Howell, J. E., and Fahrig, W. F.
 1972: A geological cross-section of the Labrador miogeosyncline near Schefferville, Quebec; Geol. Surv. Can., Paper 70-37
- Hofmann, H. J.
 1971: Precambrian fossils, pseudofossils, and problematica in Canada; Geol. Surv. Can., Bull. 189
 1975: Stratiform Precambrian stromatolites, Belcher Islands, Canada: relations between silicified microfossils and microstructure; Am. J. Sci., v. 275, p. 1121-1132
 1976: Precambrian microflora, Belcher Islands, Canada: significance and systematics; J. Paleontol., v. 50, p. 1040-1073
- Holland, H. D.
 1973: The oceans: a possible source of iron in iron-formations; Econ. Geol., v. 68, p. 1169-1172

- Hough, J. L.
1958: Fresh water environment of deposition of Precambrian banded iron formations; J. Sediment. Petrol., v. 28, p. 414-430
- Howell, J. E.
1954: Silicification in the Knob Lake Group of the Labrador iron belt; unpublished PhD. thesis, University of Wisconsin
- James, H. L.
1954: Sedimentary facies of iron formation; Econ. Geol., v. 49, p. 235-293
1966: Chemistry of iron-rich sedimentary rocks; U.S. Geol. Surv., Prof. Pap. 440-W
- Jones, H. A.
1965: Ferruginous oolites and pisolites; J. Sediment. Petrol., v. 35, p. 832-845
- Kahle, C. F.
1966: Some observations on compaction and consolidation in ancient oolites; The Compass of Sigma Gamma Epsilon, v. 44, p. 19-29
- Kelley, V. C.
1951: Oolitic iron deposits of New Mexico; Am. Assoc. Pet. Geol., Bull., v. 35, p. 2199-2228
- Kimberley, M. M.
1974: Origin of iron ore by diagenetic replacement of calcareous oolite; unpublished PhD. thesis, Princeton University
- Klein, C.
1974: Greenalite, stilpnomelane, minnesotaite, crocidolite and carbonates in a very low-grade metamorphic Precambrian iron formation; Can. Mineral., v. 12, p. 475-498
- Klein, C. and Fink, R. P.
1976: Petrology of the Sokoman iron formation in the Howells River area, at the western edge of the Labrador Trough; Econ. Geol., v. 71, p. 453-487
- Krishnan, T. K.
1976: Structural studies of the Schefferville Mining District, Quebec-Labrador, Canada; unpublished PhD. thesis University of California, Los Angeles

La Berge, G. L.

1967: Microfossils and Precambrian iron-formations;
Geol. Soc. Am., Bull., v. 78, p. 331-342

1973: Possible biological origin of Precambrian
iron-formations; Econ. Geol., v. 68, p. 1098-1109

Lepp, H. and Goldich, S. S.

1959: The chemistry and origin of iron formations;
Geol. Soc. Am., Bull., v. 70, p. 1637

1964: Origin of the Precambrian iron formations;
Econ. Geol., v. 59, p. 1025-1060

Lowdon, J. A.

1960: Age determinations by the Geological Survey
of Canada, Report 1 isotopic ages; Geol. Surv.
Can., Paper 60-17

1961: Age determinations by the Geological Survey
of Canada, Report 2 isotopic ages; Geol. Surv.
Can., Paper 61-17

MacLeod, W. N.

1966: The geology and iron deposits of the Hamersley
Range area, Western Australia; West. Aust.
Geol. Surv., Bull. 117

Moore, E. S. and Maynard, J. E.

1929: Solution, transportation, and precipitation of
iron and silica; Econ. Geol., v. 24, p. 272-303,
365-402, 506-527

McConnell, R. L.

1974: Preliminary report of microstructures of
probable biologic origin from the Mescal For-
mation (Proterozoic) of central Arizona; Pre-
cambrian Research, v. 1, p. 227-234

Newell, N. D., Purdy, E. G., and Imbrie, J.

1960: Bahamian oolitic sand; J. Geol., v. 68, p.
481-497

Oehler, J. H.

1976: Hydrothermal crystallization of silica gel;
Geol. Soc. Am., Bull., v. 87, p. 1143-1152

Oehler, J. H. and Schopf, J. W.

1971: Artificial microfossils, experimental studies
of permineralization of blue-green algae in
silica; Science (AAAS), v. 174, p. 1229-1231

Pettijohn, F. J.

1975: Sedimentary Rocks; Harper and Row Publishers

- Plfeider, E. P. et al
 1968: Mesabi deep drilling project progress report
 no. 1; University of Minnesota Publication
- Sakamoto, T.
 1950: The origin of the Precambrian banded iron ores,
 Am. J. Sci., v. 248, p. 449-474
- Sarkar, B.
 1973: Deformed oolites in the Precambrian Bhandar
 Limestones; India; J. Sediment. Petrol., v.
 43, p. 636-643
- Schopf, J. W.
 1974: The development and diversification of Pre-
 cambrian life; Origins of Life, v. 5, p.
 119-135
- 1975: Precambrian paleobiology: problems and pers-
 pectives; in Annual Review of Earth and Plane-
 tary Sciences, v. 3, p. 213-249
- 1977: Biostratigraphic usefulness of stromatolitic
 Precambrian microbiotas: a preliminary
 analysis; Precambrian Research, v. 5, p. 143-
 173
- Schopf, J. W. and Blacic, J. M.
 1971: New microorganisms from the Bitter Springs
 Formation (late Precambrian) of the north-
 central Amadeus Basin, Australia; J. Paleontol.,
 v. 45, p. 925-960.
- Seguin, M.
 1963: Geology of Knob Lake Ridge Schefferville,
 Quebec; unpublished MSc. thesis McGill Univer-
 sity.
- Siever, R.
 1957: Silica budget in the sedimentary cycle; Am.
 Mineral., v. 42, p. 821-841
- Spencer, G.
 1971: Chert in sediments; Inst. Lake Superior Geol.
 (17th Ann. Mtg.), Duluth, Minnesota, p. 62
- Stubbins, J. B., Blais, R. A., and Zajac, I. S.
 1961: Origin of the soft iron ores of the Knob Lake
 Range; Can. Inst. Min. Met., Trans., v. 64,
 p. 37-52
- Taliaferro, N. L.
 1934: Contraction phenomena in cherts; Geol. Soc.
 Am., Bull., v. 45, p. 196-197

- Todd, J. E.
1903: Concretions and their geological effects; Geol. Soc. Am., Bull., v. 14, p. 353-368
- Van Hise, C. R. and Leith, C. K.
1911: Geology of the Lake Superior region; U.S. Geol. Surv., Mon. 52
- Walther, J.
1893-94: Einleitung in die Geologie als historische Wissenschaft; Gustav Fischer Verlag, Jena, 3 volumes
- Wentworth, C. K.
1922: A scale of grade class terms for clastic sediments; J. Geol., v. 30, p. 377-392
- Woolnough, W. G.
1941: Origin of banded iron deposits - a suggestion; Econ. Geol., v. 36, p. 465-489
- Zajac, I. S.
1974: The stratigraphy and mineralogy of the Sokoman Formation in the Knob Lake area, Quebec and Newfoundland; Geol. Surv. Can., Bull. 220

APPENDIX I

LEGEND FOR MAP

Outcrop

Small Scattered Outcrop

Scree or Talus - from frost action only

Geological Contact - in outcrop

Strike and Dip of Bedding - inclined

- vertical

Strike and Dip of Joints - inclined

- vertical

Anticline Axis - showing plunge and dip of axial plane

Syncline Axis - showing plunge and dip of axial plane

Fault - in outcrop

Roads

Shoreline of Lake, Pond or River

Swamp - or marsh

Enriched Iron Formation (Medium) - visible replacement by hematite, goethite, limonite, manganese by volume $>10\% < 20\%$

E (mn)

Geological Interpretation is Superposed on the Map

- Geological Contacts

- Fault

LEGEND FOR MAP (continued)

Menihek Formation (MS)	
	Sokoman Formation
Lean Chert (LC)	Upper Iron Formation Member
Grey Upper Iron Formation (GUIF)
Pink Grey Cherty Iron Formation (PGC)	Middle Iron Formation Member
Lower Red Cherty Iron Formation (LRC)
Lower Iron Formation (LIIf)	Lower Iron Formation Member
Ruth Submember (RF)
Wishart Formation (Qte)
Fleming Formation (CB)
Undifferentiated Iron Formation (IF)

MAP 1: REPRESENTATIVE PORTION OF THE 200 SCALE DETAILED MAPPING

(from the central area of map sheet 6 - 15 in the IOC grid)

Scale: 200 0 200 400 feet
100 0 100 metres

LEGEND OF SYMBOLS USED IN THE STRATIGRAPHIC COLUMNS

CARBONATES

IRON OXIDES

CONCRETIONS

DISSEMINATED (IRON OXIDES)

GRANULAR, OOLITIC

LENSED

CROSS BEDDED

THIN BEDDED (<1cm)

MEDIUM BEDDED (1-4 cm)

THICK OR MASSIVE BEDDED (>4 cm)

SCALE : one inch = 30.5 metres
(for all columns)

Stratigraphic Column for Section 1

SECTION I (field descriptions):

- MS - fissile, carbonaceous shale (beds approximately $\frac{1}{4}$ inch thick)
- greenish brown on weathered surface, black on fresh surface
 - some evidence of polygonal jointing weathering and fracturing produce "shingle-like" fragments
- UIF - the UIF in this area is not easily divisible into distinct units, rather it tends to be a gradational unit consisting of interpenetrating facies of the LC and GUIF Submembers
- LC material - massive, occasionally medium bedded
- outcrop has a fragmental-like texture overall
 - consists predominantly of green and red chert with minor iron oxides
 - locally the beds are predominantly green chert, but generally it is green to wine coloured on fresh and weathered surfaces
- GUIF material - massive to thick bedded
- granular chert distinctive in this section
 - commonly exhibits mottled or "salt and pepper" texture
 - abundant pock marking (due to carbonate leaching)
 - disseminated iron oxides, predominantly blue hematite
 - greyish white or wine coloured
 - locally contains minor jasper
- [URC is not distinguishable as a mappable unit in this area.
- PGC - upper part of the unit is a pinkish brown cherty facies with abundant granular and oolitic (?) textures
- central part of the unit is predominantly a massive grey and a massive pink-grey cherty facies composed of white chert, jasper, blue hematite and magnetite
 - locally this portion of the unit contains jasper lenses and bands
 - the lower part of the unit predominantly irregular lenses of greenish white chert and red hematite (texturally similar to cherty RF)

- locally contains shaly beds and small spheroids of chert altering to a greyish clayey material
 - the basal portion of the unit is predominantly blue hematite and brown chert
- LRC
- thin, diffuse banding (laminated)
 - purplish grey in colour but locally contains brown chert
 - the bands are dull red to purplish red jasper
 - thin laminations and patches of blue hematite and magnetite
 - minor secondary goethite in cavities and some limonite staining
- LIF
- well laminated
 - laminations consist of iron silicates, hematite, magnetite, and chert
 - locally contains irregular lenses of greyish white chert
 - some minor enrichment in the form of columnar goethite along fracture surfaces
- RF
- the upper part of the unit is a cherty facies consisting predominantly of red hematite lenses in greyish black chert and is highly fractured
 - the central portion of the unit is a fissile, ferruginous shale with some evidence of polygonal jointing
 - the basal part of the unit is thicker bedded shale which is highly fractured and has abundant limonite staining
- Qte
- light grey to buff, coarse-grained arkosic quartzite
 - average thickness of bedding approximately 2 feet
 - locally has extremely coarse-grained layers (1 inch to 1 foot thick) with angular grains up to 0.2 inches
 - contains some thin shaly interbeds
 - some evidence on outcrop surfaces of possible cross-bedding

Stratigraphic Column for Section 2

SECTION 2 (field descriptions):

- MS - thinly bedded, fissile, carbonaceous shale
- greenish-brown on weathered surface, black on fresh surface
- minor limonite staining along bedding planes
- LC - predominantly green and purplish chert with minor iron oxides
- locally contains bands of aphanitic black chert (2" - 4" thick)
- locally appears to be highly brecciated
- the upper portion of the unit contains a pronounced magnetic shale facies

- Magnetic shale facies - poorly developed bedding (approximately 4 inches thick)
- locally contains thin bedded, fissile portions
- greenish black, fine-grained rock
- contains disseminated magnetite
- minor limonite and limonite staining
- sometimes has pyrite crystals on fracture surfaces
- numerous small alteration spots - carbonates?

- GUIF - medium bedded, poorly layered
- blotchy appearance due to brown alteration patches (carbonate limonite/goethite)
- lenses of iron oxides containing disseminated chert
- green and white granular chert with limonite staining

[URC is not distinguishable as a mappable unit in this section.

- PGC - predominantly massive to well banded pink-grey cherty facies
- chert tends to be massive with a granular texture
- iron oxides form somewhat discontinuous layers
- limonite staining

[LRC is not distinguishable as a mappable unit in this section.

- LIF - well laminated unit (approximately $\frac{1}{4}$ inch on average)
- laminations composed of white chert, red and blue hematite, and iron silicates
- minor limonite staining

- RF - thinly bedded, extremely fissile, reddish black, ferruginous shale
- basal part of the unit not exposed
- Qte - some poor exposures of black chert, mark the upper limit of the Qte
- thick- to medium-bedded arkosic quartzite
- well rounded quartz grains, leached and altered feldspar, and minor secondary red hematite

Stratigraphic Column for Section 3

SECTION 3 (field descriptions):

- LC - predominantly fine grained, massive red and green chert
 - some red hematite staining
 - minor jasper granules
- GUIF - massive cherty unit
 - predominantly grey and brown chert with iron silicates and minor iron oxides (mostly disseminated blue hematite and magnetite)
 - some granular white chert disseminated through outcrop
 - outcrop has a thick weathering rind and limonite staining
- WRC - massive to poorly banded, pink-grey, granular, cherty unit
 - upper part of the unit quite granular with carbonate leaching
 - lower part of the unit quite granular and also contains chert lenses (mostly jasper)
- PGC - upper part of the unit predominantly brown chert, iron silicates, and iron oxides, shows some banding
 - middle of the unit granular grey-white chert with disseminated iron oxides
 - some $\frac{1}{4}$ inch bands of magnetite
 - locally contains secondary manganese
 - lower part of the unit is generally well banded ($\frac{1}{4}$ " - 1")
 - predominantly grey-white cherty material with some brown chert
- LRC - consists of chert and iron oxide lenses, bands, and granules
 - possible soft sediment deformation
 - numerous large granular fragments
- ✓ SCIF - predominantly brown chert and limonite with minor magnetite
- RF - predominantly thinly bedded and extremely fissile
 - some thicker beds approximately 4 inches
 - has some cherty interbeds
 - abundant limonite

Stratigraphic Column for Section 4

SECTION 4 (field descriptions):

[There is field evidence of several faults in this area resulting in the repetition of many of the units.

- MS - fissile, black carbonaceous shale
- greenish brown on weathered surface, black on fresh
- weathers into "shingle-like" slabs
- LC - massive cherty unit, locally highly fractured
- predominantly grey and white chert with minor jasper granules
- locally contains lenses of green and black chert
- disseminated iron oxides (mostly magnetite)
- in the upper portion of the unit there is a bed ($\frac{1}{2}$ to 1 foot thick) exposed which contains numerous elongated chert fragments (most of the fragments are parallel to bedding but a few are perpendicular to bedding)
- upper portion of the unit also contains a magnetic shale facies

Magnetic shale facies - fine- to medium-grained, massive silicate unit

- highly magnetic, magnetite is disseminated but also occurs as distinct thin bands or laminations
- prevalent limonite staining

- GUIF - fine- to medium-grained massive but locally thinly bedded
- chert, disseminated iron oxides (magnetite and hematite) and brown silicate minerals
- generally grey-white on weathered surface and grey-black with white spots on fresh surface
- abundant limonite staining
- locally abundant pock marks filled with secondary red hematite (more predominant in upper portion of the unit)

[URC is not distinguishable as a mappable unit in this area, but locally there are some jasper bands in the vicinity of UIF/MIF contact.

- PGC - predominantly fine- to medium-grained, massive, cherty unit
- predominantly grey-white, granular-textured chert with disseminated iron oxides
- locally contains bands and lenses of chert (red and brown) (these tend to be quite irregular)
- jasper granules quite common in upper part of the unit

- lower part of the unit is highly fractured
- locally contains abundant pock marks
- limonite and manganese (botryoidal) enrichment abundant along fracture and fault surfaces
- one or two spots in the unit appeared as though they might be graded sequences
- one spot in the lower part of the section had numerous concretionary structures

- LIF
- predominantly a well banded cherty unit with disseminated iron oxides.
 - brown and white chert in discontinuous bands and lenses
 - locally fissile

SECTIONS 5 and 6:

Due to the sporadic and sparse nature of the outcrop in this area it was not possible to measure stratigraphic sections.

Stratigraphic Column for Section 7

SECTION 7 (field descriptions):

- IC - massive green chert with very minor amounts of disseminated magnetite
 - predominantly green chert
- GUIF - predominantly grey-green chert with disseminated magnetite
 - thin ($\frac{1}{4}$ ") bands of white chert
 - a few thin laminations of magnetite
 - abundant pock marking
 - minor limonite staining
 - locally has a fragmental appearance
- MIF - massive, fine- to medium-grained, green-grey chert and disseminated magnetite
 - granular texture predominant throughout unit
 - much of the magnetite occurs as thin laminations ($\frac{1}{8}$ " - $\frac{1}{16}$ ")
 - locally contains secondary red hematite and limonite
 - locally has pronounced pock marking
 - locally has disseminated jasper granules
 - limonite staining on bedding surfaces and within the layers

LRC not distinguishable as a mappable unit in this area, although the base of the MIF locally has a few small outcrops of thinly banded purplish red jasper iron silicates, hematite, and magnetite.

- LIF - well banded, thin bedded, locally massive
 - thin laminations and small lenses of jasper
 - predominantly white chert and iron silicates which weather yellowish brown
 - locally coarse-grained fragments in a somewhat earthy matrix
- RF - grey-green, fine-grained, fissile shale/siltstone
 - beds approximately $\frac{1}{8}$ inch, some beds $\frac{1}{4}$ to 1 inch
 - some thin goethite beds and minor red hematite and goethite
 - abundant limonite staining on bedding surfaces

Stratigraphic Column for Section 8

SECTION 8 (field descriptions):

- GUIF - massive cherty unit
- very lean, with very few iron oxides
 - predominantly reddish white chert, with a few minor, discontinuous bands of iron oxide (mostly red hematite)
 - locally parts of the unit are more banded, due to the occurrence of $\frac{1}{8}$ inch bands of greenish white chert
 - some minor pock marking

[URC not distinguishable as a mappable unit in this area.]

- MIF - well banded, fine- to medium-grained cherty unit
- chert bands $\frac{1}{4}$ to $\frac{1}{2}$ inch
 - iron oxide bands $\frac{1}{8}$ to $\frac{1}{4}$ inch (mostly blue hematite)
 - chert is predominantly pinkish brown

[LRC is not distinguishable as a mappable unit in this area.]

- LIF - irregular bands of iron oxide (approximately $\frac{1}{8}$ to $\frac{1}{4}$ inch) in a fine- to medium-grained brown cherty material
- RF - thinly bedded, fissile black carbonaceous shale
- fine-grained
 - greenish brown on weathered surface, black on fresh surface

SECTION 9 (field descriptions):

- URC/PGC - upper part of the unit tends to be a predominantly white-grey, massive cherty facies
- locally has patches of red hematite stained material
 - lower part of the unit is more banded ($1/4$ to $3/4$ inches) and consists of abundant pink and reddish chert, plus blue hematite and minor white chert
- LRC - well banded ($\frac{1}{2}$ to 1 inch)
- jasper, blue hematite and iron silicates
 - bands are blue hematite, with a few white chert bands
 - remainder of material is highly oolitic and granular
- IIF - fine-grained, fissile, highly fractured
- yellowish green on weathered surface
 - abundant limonite
- RF - laminated to thinly bedded
- predominantly blue hematite, with red hematite, white chert and minor goethite
 - much harder than typical RF
- Qte - medium-grained arkosic quartzite

Key For Correlating Photographic Plates to Sample Site
Locations And Thin Sections

<u>Figure Number</u>	<u>Thin Section No. or Sample Site</u>	<u>Figure Number</u>	<u>Thin Section No. or Sample Site</u>
6	RS	49	112
7	1	50	GC
8	37	51	112
9	3	52	GC
10	82	53	GC
11	6	54	39
12	6	55	16
13	27	56	32
14	11	60	15.1
15	11	61	15
16	60	62	15
17	112	63	GC
18	60	64	15
19	GC	65	15
20	GC	66	15
21	GC	67	16
22	66		
23	GC		
24	GC		
25	112		
26	15.1		
27	GC		
28	60		
32	15		
33	112		
34	6		
35	34.1		
36	34.1		
37	6		
38	34		
39	6		
40	6		
41	6		
42	60		
43	6		
44	6		
45	27.1		
46	15		
47	112		
48	112		

(Note: thin sections are numbered with the same number as the sample site.)

Lojona Lake

San Juan Lake

Section 2

Abut. Lake

Upper Lake

2 of 1

Section I

Gliding Lake

Lee Lake

Section 4

Reynolds Lake

| 4 of |

Rough Line

| 5 of |

MAP 2 : COM

MEY

(HUN

6 of 6

**COMPOSITE MAP OF THE STUDY AREA ILLUSTRATING LOCATION OF
MEASURED SECTIONS AND SAMPLE SITES**

(Showing sections A-3 and B-3 in the ICG grid)

END

1	0	0	9	H	8	4
---	---	---	---	---	---	---

FIN