



National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service

Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

NOTICE

The quality of this microform 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 an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme 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 qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30, et ses amendements subséquents.

PROVENANCE AND DEPOSITIONAL FACIES OF
SURFICIAL SEDIMENTS IN HUDSON BAY,
A GLACIATED EPEIRIC SEA

by
Penny J. Henderson

This thesis was written under the auspices of
the Ottawa-Carleton Geoscience Centre

A thesis submitted to the School of Graduate Studies
University of Ottawa in partial fulfillment
of the degree of
Doctor of Philosophy
Department of Geology



Penny J. Henderson, Ottawa, Canada, 1990



National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service Service des thèses canadiennes

Ottawa, Canada
K1A 0N6

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-60039-X



UNIVERSITÉ D'OTTAWA
UNIVERSITY OF OTTAWA

To my parents,
Helen and Les Wise

ABSTRACT

PROVENANCE AND DEPOSITIONAL FACIES OF SURFICIAL SEDIMENTS
IN HUDSON BAY, A GLACIATED EPEIRIC SEA

A model for Wisconsinan glaciation and deglaciation of Hudson Bay is proposed based on depositional facies of the surficial sediments. These facies, defined on the basis of texture, composition, and acoustic character, indicate that sediment distribution is controlled primarily by Late Wisconsin glaciation. Post-glacial sedimentation is restricted to the shallow marine environment (<100m deep) and involves reworking of glacially-derived sediments by rivers and/or marine currents. Deposition due to sea-ice rafting is minor.

Within the glacial sediments, dispersal trends of distinctive lithologies and mineralogies (derived from sources adjacent to and underlying the bay) indicate that (1) western Hudson Bay was glaciated by ice flow eastward from a centre in the District of Keewatin, and (2) the eastern and southern bay was glaciated by ice flow westward from a dispersal centre in Nouveau Quebec. Seafloor geomorphic features and sediment composition suggest that deglaciation was focused at the confluence between these two ice sheets, possibly through ice streaming and calving bay formation. Eastward and southward dispersal of sediment derived from sources within the bay suggest a residual ice mass remained centered over Hudson Bay following glacial maximum.

The deglaciation model invokes stabilization of the ice margin in the north, extension of a calving bay in Hudson Strait into west-central Hudson Bay, northward drainage of proglacial lakes along major bathymetric depressions, and, finally, rapid collapse of the ice sheet.

RÉSUMÉ

PROVENANCE ET FACIÈS DE DÉPOSITION DES SÉDIMENTS DE SURFACE
DE LA BAIE D'HUDSON, UNE MER ÉPEIRIQUE ENGLACÉE

Un modèle de la glaciation et la déglaciation du Wisconsinien de la Baie d'Hudson est proposé d'après les faciès des sédiments de surface. Ces faciès sont définis par leur texture, leur composition et leurs propriétés acoustiques. Ils indiquent que la sédimentation était surtout contrôlée par la glaciation du Wisconsinien tardif. La sédimentation post-glaciaire est restreinte à un environnement marin peu profond (à <100m de profondeur), ce qui comprend des sédiments glaciaires remainés par les rivières et/ou les courants marins. La sédimentation glacielle est mineure.

Parmi les sédiments glaciogéniques, il y a des traînées de dispersion lithologiques et minéralogiques distinctives dérivées de sources rocheuses adjacentes et sous-jacentes à la baie et elles indiquent que (1) la partie ouest de la Baie d'Hudson a été englacée par un mouvement glaciaire allant de l'ouest vers l'est provenant d'un centre glaciaire situé dans le territoire du Keewatin et (2) les parties est et sud de la Baie d'Hudson ont été affectées par un mouvement glaciaire allant vers l'ouest et issu d'un centre de dispersion situé au Nouveau-Québec. Les caractéristiques géomorphologiques du fond marin et la composition des sédiments suggèrent que la déglaciation a eu lieu au contact de ces deux nappes glaciaires, peut-être par la formation de courants glaciaires et d'une baie de vélage. La dispersion vers l'ouest et vers le sud des sédiments provenant de sources rocheuses sous la baie suggère qu'une nappe glaciaire résiduelle est demeurée au centre de la Baie d'Hudson après le maximum glaciaire.

Le modèle de déglaciation proposé invoque la stabilisation de la marge glaciaire au nord, l'extension de la baie de vélage du Détroit d'Hudson vers le centre-ouest de la Baie d'Hudson, le drainage vers le nord de lacs proglaciaires au long des dépressions bathymétriques majeures et finalement, l'effondrement de la nappe glaciaire.

ACKNOWLEDGMENTS

I would like to express my deepest thanks and appreciation to Dr. Brian Rust and Dr. W.W. Shilts for their advice, encouragement, and faith in my ability to complete this project. They both provided support and inspiration at many stages throughout thesis development. Funding for parts of the study was provided by research grants to Dr. Rust.

I am indebted to the Terrain Sciences Division (Dr. D.A. St.-Onge, Division Director, and Dr. J.S. Scott, Director General) and the Atlantic Geoscience Centre, Geological Survey of Canada, for making their facilities, analytical results, and sample material available for this study. Dr. Bern Pelletier and Iris Hardy and her staff generously offered their time and expertise to search the hidden corridors of archived sample collections. Dr. Pelletier and Bruce Sanford provided field notes and observations from previous marine geological investigations. John Zevenhuisen shared the results of his compilation of Hudson Bay samples and seismic records. Heiner Josenhans and Dr. Denis St.-Onge arranged for my participation in marine surveys in Hudson Bay (HU-86-040 and HU-87-028). Rob Burns provided much needed computer assistance and produced the appmap plots. Thanks are also extended to Ron Kelly and Patti Higgins of the Terrain Sciences sedimentology laboratory for grain size analyses, sample preparation, and Leco carbonate determinations, Bob Delabio for clay mineralogy, and to Graham Wiley and everyone in the photomechanical section.

This research was also supported by post-graduate scholarships to the author from the Government of Ontario, Natural Sciences and Engineering Research Council and the University of Ottawa. Many others contributed to various aspects of this research and provided enlightenment through discussion, es-

pecially Christine Kaszycki, Harvey Thorliefson, Heiner Josenhans, Eric Nielsen, Rod Klassen, Ron DiLabio, Dominique Pare, Bruce Sanford, Linda Dredge and Mark Nixon. Graham Buckley, University of Ottawa, capably performed heavy mineral separations. Andree Blais, Carleton University, kindly translated the abstract.

Finally, I would like to thank my friends and family for their moral and, at times, practical support during the completion of this thesis. Thanks to Chris, Patti, Inez and Harvey. To my husband, John, and our children, Elizabeth and Brian, a special thanks for their continuing patience, encouragement and adaptability. I could not have done it without them.

TABLE OF CONTENTS

	PAGE
LIST OF TABLES	xii
LIST OF ILLUSTRATIONS	xiii
 CHAPTER I: INTRODUCTION	
1.1 Objectives of Study	1
1.2 Previous Work	3
1.3 Data Acquisition and Method of Study.....	4
1.4 Regional Setting	8
1.5 Bathymetry	10
1.6 Bedrock Geology	12
1.6.1 Shield Terrane	12
1.6.2 Paleozoic Terrane	16
1.7 Quaternary Geology	17
1.7.1 Quaternary Stratigraphy	17
1.7.2 Dispersal Trends and Landforms	20
1.7.3 Deglaciation	22
 CHAPTER 2: SEISMIC ANALYSIS AND CORE DESCRIPTION	
2.1 Introduction	24
2.2 Acoustic Facies	24
2.2.1 Description	26
2.2.2 Distribution	26
2.3 Acoustic Geomorphic Features	38
2.3.1 Description	38
2.3.2 Distribution	42
2.3.3 Interpretation	50
2.4 Core Descriptions	53
2.5 Discussion	56
 CHAPTER 3: TEXTURAL CHARACTERISTICS OF SURFICIAL SEDIMENTS	
3.1 Introduction	58

3.2	Data Evaluation	58
3.3	Regional Textural Variations	62
3.3.1	Gravel Distribution	62
3.3.2	Sand Distribution	64
3.3.3	Silt/Clay Distribution	66
3.4	Characteristics of Grain Size Distribution ...	66
3.4.1	Definition of Sediment Types	69
3.4.2	Distribution of Sediment Types	74
3.5	Summary	76
 CHAPTER 4: COMPOSITION, PROVENANCE AND DISPERSAL TRENDS		
4.1	Introduction	78
4.2	Analytical Methods	79
4.2.1	Gravel Fraction	81
4.2.2	Fine Sand Fraction	82
4.2.3	Fine-grained Fraction	83
4.3	Contour Methods	84
4.4	Analysis of the Gravel Fraction	85
4.4.1	Distribution and Dispersal Trends	86
4.4.2	Interpretation of Dispersal Trends	96
4.5	Heavy Mineral Analysis	101
4.5.1	Heavy Mineral Assemblages	101
4.5.2	Siderite Distribution and Provenance	111
4.5.3	Interpretation	116
4.6	Mineralogical and Chemical Analysis of Clay-size Fraction	119
4.6.1	Mineralogy	121
4.6.2	Geochemistry of Clay-size Fraction	124
4.6.3	Interpretation of Base Metal Distribution..	138

4.7	Carbonate Content of Surficial Sediment	143
4.7.1	Carbonate Distribution	143
4.7.2	Interpretation	146
4.8	Summary	147

**CHAPTER 5: DEPOSITIONAL FACIES: IMPLICATIONS FOR THE
GLACIAL HISTORY OF HUDSON BAY**

5.1	Introduction	149
5.2	Definition of Depositional Facies	149
5.3	Facies Interpretation	153
5.3.1	Coarse-grained Facies (A,B,C)	153
5.3.2	Fine-grained Facies (D)	156
5.4	Processes of Sedimentation and Sediment Modification	157
5.4.1.	Fluvial Systems	157
5.4.2.	Ocean Processes	160
5.4.3.	Sea-ice Rafting	165
5.4.4.	Biogenic Processes	166
5.4.5.	Eolian Processes	166
5.5	Sedimentation Model	167
5.6	Implications for Glacial History of Hudson Bay	169
5.6.1.	Glaciation	169
5.6.2.	Deglaciation	172
5.7	Summary	174

CHAPTER 6: LATE WISCONSIN AND HOLOCENE HISTORY, HUDSON BAY

6.1.	Introduction	176
6.2	Configuration and Dynamics of the Laurentide Ice Sheet	176
6.3	Model for Glaciation and Deglaciation	179
6.3.1.	Glaciation	179
6.3.2.	Deglaciation	183
6.4	Discussion	194
6.5.	Further Research	195

CHAPTER 7: CONCLUSION	197
REFERENCES	199
APPENDICES	223
A Summary of Sample Locations and Analyses	224
B Core Description and Interpretation	236
C Grain-size Analyses	243
D Appmap Programs: Plotting Method for Grain- size Data	255
E Lithological Analyses	256
F Heavy Mineral Analyses	261
G Geochemical Analyses	270
H Mineralogy of Clay-size Fraction	276
I Leco Carbonate Determinations	277
J Trend Surface Analyses of Heavy Mineral Data.	281

LIST OF TABLES

	Page
1. Acoustic Facies	27
2. Iceberg Scour Types	43
3. Sampling and Analytical Procedures, Grain-size Data	59
4. Characteristic Heavy Mineral Suites from Major Geological Terranes, Hudson Bay	102
5. Depositional Facies of Surficial Deposits, Hudson Bay	150
6. Hudson Bay Core Data.....	237
7. Diamict Lithofacies Code and Symbols.....	240

LIST OF ILLUSTRATIONS

	Page
Chapter 1	
1.1 Location of Hudson Bay in the centre of the area covered by the Laurentide Ice Sheet	2
1.2 Distribution of sample sites in Hudson Bay	6
1.3 Major geographic features of the Hudson Bay region.	9
1.4 Bathymetry of Hudson Bay	11
1.5 Bedrock geology of Hudson Bay region	13
1.6 Quaternary stratigraphy of the Hudson Bay Lowlands.	18
1.7 Quaternary geology of the Hudson Bay region	21
Chapter 2	
2.1 Seismic lines from oceanographic surveys in Hudson Bay	25
2.2 Relationship between sedimentary and acoustic facies at site of core HU-87-028-001	28
2.3 Thickness of surficial sediment, Hudson Bay	29
2.4 Distribution of acoustic facies, Hudson Bay	30
2.5 Variation in style of sedimentation over Precambrian and Paleozoic bedrock surface	31
2.6 Huntec sub-bottom profile showing thin sediment cover over Paleozoic bedrock, central Hudson Bay .	33
2.7 Huntec sub-bottom profile showing effects of iceberg scour on acoustic character of sediment ..	34
2.8 Huntec sub-bottom profile of large asymmetric moraines offshore from the District of Keewatin ..	35
2.9 Huntec profile showing sedimentation in Winisk Trough	36
2.10 Huntec profile showing post-glacial sediment infill, southwestern Hudson Bay	37
2.11 Sidescan sonographs of glacial flutings and/or corduroy features	39

2.12 Sidescan sonograph showing unscoured, mottled seafloor on Mansel Bank, northeastern Hudson Bay .	41
2.13 Sidescan sonographs showing iceberg scour types ...	44
2.14 Sidescan sonograph of transverse bedforms offshore from Nelson River estuary	46
2.15 Channels in southern Winisk Trough	47
2.16 Distribution of seafloor geomorphic features, Hudson Bay	48
2.17 Relationship between bathymetry and distribution of seafloor features	49

Chapter 3

3.1 Effects of disaggregation on grain-size distribution	61
3.2 Appmap plot showing gravel (> 2mm) content of surficial sediment	63
3.3 Appmap plot showing sand (0.063 -2mm) content of surficial sediment	65
3.4 Appmap plot showing silt (0.004 - 0.063 mm) content of surficial sediment	67
3.5 Appmap plot showing clay (< 0.004mm) content of surficial sediment	68
3.6 Plot of sorting coefficient versus mean grain-size for 1971 samples	70
3.7 Ternary plot of matrix composition for 1971 samples	73
3.8 Distribution of sample types in Hudson Bay	75

Chapter 4

4.1 Site locations for compositional analyses in relation to sediment type	80
4.2 Distribution of igneous/metamorphic clasts in surficial sediment	87

4.3	Distribution of grey to tan carbonate clasts in surficial sediment	89
4.4	Distribution of red/pink carbonate clasts in surficial sediment	91
4.5	Distribution of greywacke/argillite clasts in surficial sediment	93
4.6	Distribution of Dubawnt Group clasts in surficial sediment	95
4.7	Relationship between distribution and dispersal trends of Dubawnt Group, greywacke/argillite, and red/pink carbonate in seafloor sediment	97
4.8	Distribution of heavy mineral assemblages	103
4.9	Hematite distribution in Hudson Bay	106
4.10	Plot of hematite concentration vs. depth	107
4.11	Relationship between concentrations of hematite and Proterozoic erratics in surficial sediments...	109
4.12	Distribution of siderite	112
4.13	Plot of siderite concentration, sediment type and depth	114
4.14	Offshore dispersal of siderite in relation to bathymetry and sediment texture	118
4.15	Sample distribution for analyses of clay-size fraction	120
4.16	X-ray diffraction patterns of clay-size fraction for selected samples	122
4.17	Cobalt distribution in clay-size fraction	125
4.18	Nickel distribution in clay-size fraction	127
4.19	Manganese distribution in clay-size fraction	128
4.20	Relationship between Co, Ni, and Mn concentration, sediment type and depth	129
4.21	Iron distribution in clay-size fraction	131
4.22	Zinc distribution in clay-size fraction	132
4.23	Relationship between Fe and Zn concentration, depth and sediment type	133

4.24	Copper distribution in clay-size fraction	135
4.25	Relationship between Cu concentration, depth and sediment type	136
4.26	Chromium distribution in clay-size fraction	137
4.27	Relationship between Cr and Pb concentration, depth and sediment type	139
4.28	Lead distribution in clay-size fraction	140
4.29	Distribution of calcium carbonate (<0.063mm)	144
4.30	Calcium distribution in clay-size fraction	145

Chapter 5

5.1	Depositional facies of surficial sediments in Hudson Bay	152
5.2	Relationship between dispersal trends and ice flow indicators in Hudson Bay and adjacent area...	154
5.3	Major processes of sedimentation and sediment modification for the shallow marine environment...	158
5.4	Variation in sorting, 1971 samples	162
5.5	Offshore textural variation along profiles from western Hudson Bay	163
5.6	Sedimentation model for surficial deposits of Hudson Bay	168
5.7	Glacial flow trends and landforms in and adjacent to Hudson Bay	170

Chapter 6

6.1	Comparison of models for the inception and growth of the Laurentide Ice Sheet	177
6.2	Possible ice flow early in the glacial history of Hudson Bay area	181
6.3	Possible ice flow during maximum extent of the Laurentide Ice Sheet	182
6.4	Deglaciation Stage 1: Development of a calving bay in Hudson Strait	184

6.5	Deglaciation Stage 2: Extension of calving bay into Hudson Bay	187
6.6	Deglaciation Stage 3: Catastrophic drainage of proglacial Lakes Agassiz and Barlow-Ojibway and incursion of Tyrrell Sea	189
6.7	Deglaciation Stage 4: Retreat of ice margin to perimeter of Hudson Bay	193

Appendices

B.1	Core locations, Hudson Bay.....	238
B.2	Core summaries, 61HB.....	239
B.3	Core summaries, HU-87-028.....	241
J.1	Segments used in trend surface analysis of heavy minerals, Hudson Bay.....	282
J.2	Resultant trend surfaces.....	286

CHAPTER 1

INTRODUCTION

1.1 Objectives of Study

Continental scale ice sheet modelling in North America has been based primarily on theoretical glaciological considerations, analogy with modern arctic and subarctic glaciers, and the regional distribution of terrestrial geomorphic features and glacial dispersal trends. A major criticism of these models, as they pertain to the Late Wisconsin Laurentide Ice Sheet, is the lack of direct geological evidence from glacial sediments at the geographic centre of the ice sheet, the area presently underlying Hudson Bay (Fig. 1.1).

The primary objective of this thesis is to present a model for Late Wisconsinan glaciation and deglaciation of Hudson Bay, based on evidence from glacially-derived seafloor sediments. This is done by a consideration of the depositional facies.

The present configuration of Hudson Bay is a remnant of the post-glacial Tyrrell Sea formed during ice recession. Marine waters entered the isostatically depressed region through Hudson Strait, drowning glacially derived sediments and landforms, and gradually regressed as the land rebounded. Consequently, the sedimentology of seafloor deposits in the bay is complex, with input from glacial, as well as fluvial and marine processes of sediment erosion, transport, deposition and modification. The recognition and characterization of seafloor sediments derived from glacial, as opposed to other sedimentary processes, would provide the geological evidence lacking in previous models for Late Wisconsin glaciation and contribute to the solution of such questions as whether the ice sheet originated in the Hudson Bay area or flowed into it from surrounding centres, and how the final disintegration of the ice sheet was accomplished.

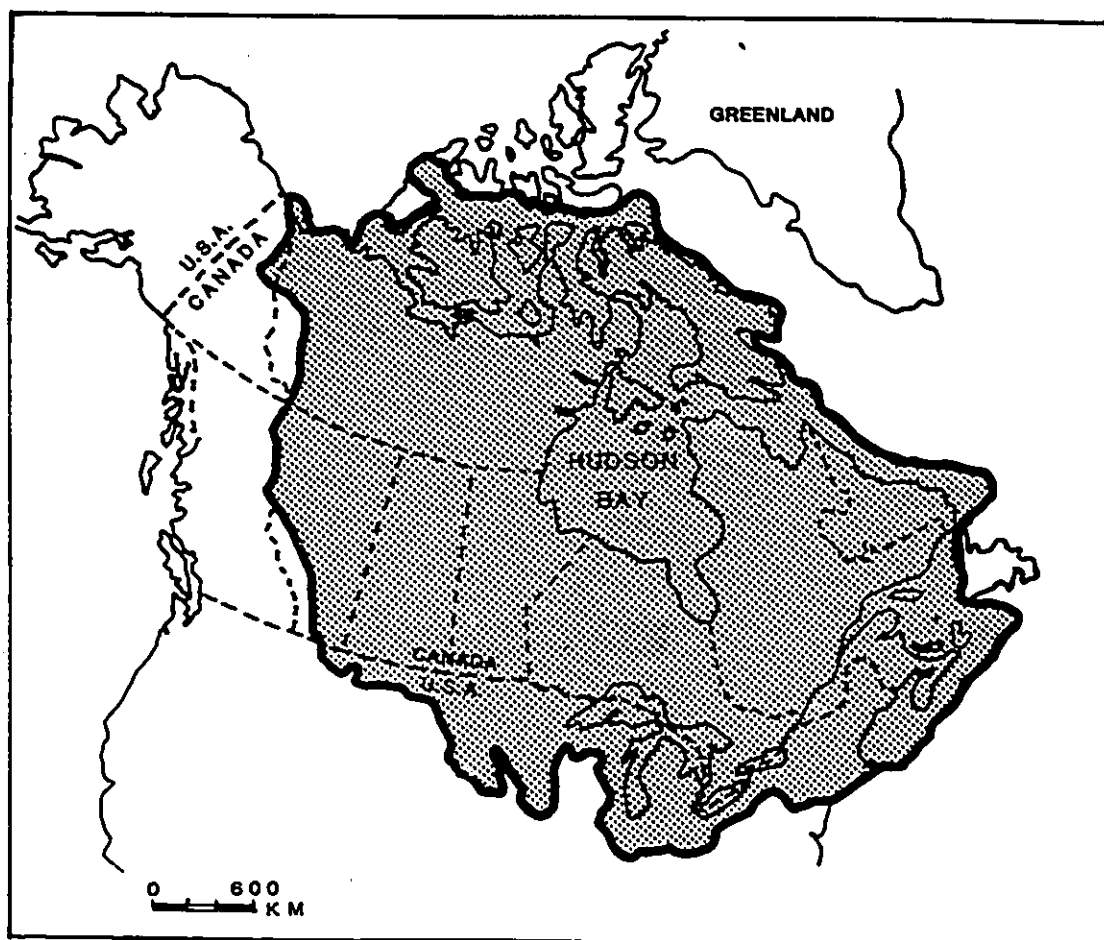


Figure 1.1: Location of Hudson Bay in the centre of the area covered by the Laurentide Ice Sheet. Stippled pattern represents the maximum extent of this ice sheet (from Fulton and Prest, 1987; pp. 182).

1.2 Previous Work

Initial observations on the geology and geomorphology of Hudson Bay were made during expeditions to coastal areas (Bell, 1885; Low, 1900, 1906). However, the first comprehensive marine geological investigations were not conducted until 1961 (Leslie, 1963; Leslie, 1964; Leslie, 1965; Leslie and Pelletier, 1965; Pelletier, 1966) and included geological sampling as well as geophysical reconnaissance. This work was followed by a more extensive program (Pelletier et al, 1968; Pelletier, 1969; Pelletier, 1986).

Both Leslie (1964, 1965) and Pelletier (1969) recognized that the unconsolidated sediments in Hudson Bay were derived, at least in part, from earlier glaciations and that post-glacial sedimentation rates were low. They interpreted sediment distribution in terms of post-glacial sedimentary processes. Based on the results of textural analyses, Pelletier (1969, 1986) presented a hydrodynamic model for sedimentation emphasizing the importance of sediment transport to the bay by rivers, and subsequent dispersal by marine currents. Coarse material (>2mm), concentrated on the southwestern and northern coasts of the Bay, was deposited by sea-ice rafting of coastal sediment. No attempt was made to relate sediment distribution to glacial processes.

Lewis and Sanford (1971) conducted shallow reflection seismic profiling, side-scan sonar, and observations from the Pisces III submersible in Hudson Bay and recognized landforms attributed to glaciation. These included sinuous ridges, interpreted as eskers or ice marginal accumulations, and iceberg scours. More recently, well site studies in western Hudson Bay by Geomarine Associates revealed well developed relic iceberg scour marks in water depths ranging from 135 to 185m (Whittaker et al, 1985). Knowledge of the areal extent of these features was expanded by Josenhans et al (1988) utilizing seismic and side-scan sonar systems. The geophysical data were

incorporated with extensive shallow penetration 3.5 khz. records collected by the Canadian Hydrographic Service during the mid 70's, resulting in an acoustic facies map and a framework for the distribution of surficial sediments based on their acoustic signature (Josenhans et al, 1988).

Conclusions from x-ray analysis of seabed samples by Bayliss et al (1970) supported Pelletier's (1969, 1986) textural interpretation that sediment dispersal was largely controlled by marine processes acting on fluvially derived sediment, and sea-ice rafting. Using the gravel fraction of the same sample set, however, Nelson (1968) reasoned that rock fragments and sediment colour were primarily a reflection of the geology of the seafloor and dismissed current action or ice rafting as major factors in sediment transport. These observations were supported by Lewis and Sanford (1971). Subsequently, lithologic and mineralogic analyses of 43 grab samples and short cores indicated that the distributions of certain rocks and mineral associations, attributed to source areas adjacent to and within the bay, were extensions of glacial dispersal trains defined on land (Shilts, 1982; Henderson, 1983a,b,). These studies were the first to suggest that much of the surficial sediment is glaciogenic, unburied because of low post-glacial sedimentation in Hudson Bay. Adshead (1983a,b,c) also concluded that sediment entering southern Hudson Bay from rivers is primarily glaciogenic debris derived from several glaciations and, subsequently, reworked during isostatic rebound.

1.3 Data Acquisition and Method of Study

Previous workers in Hudson Bay related textural and compositional variation of seafloor sediments to post-glacial sedimentary processes and bedrock geology. More recently, reconnaissance studies have shown the importance of glacial processes on sedimentation. The seeming disparity of these results indicates the necessity for a more detailed basin analysis and the estab-

lishment of a unifying sedimentation model for the surficial deposits in Hudson Bay.

It is hypothesized that few modern sedimentary processes acting in the shallow marine environment can transport coarse sediment to the central basin, other than those associated with ice, either glacial or sea-ice. If dispersal of the coarser sediment fraction in the bay can be shown to be an extension of glacially-derived sediment transport onshore, there is strong evidence to suggest the material is glacial, although possibly modified to varying degrees by modern marine processes.

In order to characterize the deposits and assess the relative sediment contribution from various sedimentary processes, surface-sediment samples and/or textural results were acquired from over 600 grab samples and a limited number of cores from Hudson Bay (Fig. 1.2). The sediments represent original and/or residual fractions of samples collected on previous marine geological surveys (Leslie, 1963, 1964; Pelletier et al, 1968; Pelletier, 1969; Lewis and Sanford, 1971; Josenhans et al, 1988) (Appendix A). Control on the sampling grid is largely a function of the original ship's track and, more importantly, the available archived material. Nevertheless, sample sites are distributed fairly uniformly throughout the bay, both in terms of geography and bathymetry.

Sediment characteristics, provenance and possible transport paths were determined through (i) the compilation and reinterpretation of textural results of seabed samples, (ii) lithologic and mineralogic analysis of various size fractions, where possible, including gravel (2-5.6mm), fine sand (0.063-0.250mm), and clay (<0.002mm), (iii) geochemistry of the clay-size fraction, and iv) calcium carbonate determinations (<0.063mm). A compilation of samples, locations and analyses is given in Appendix A. Specific procedures used in this study are described with the results.

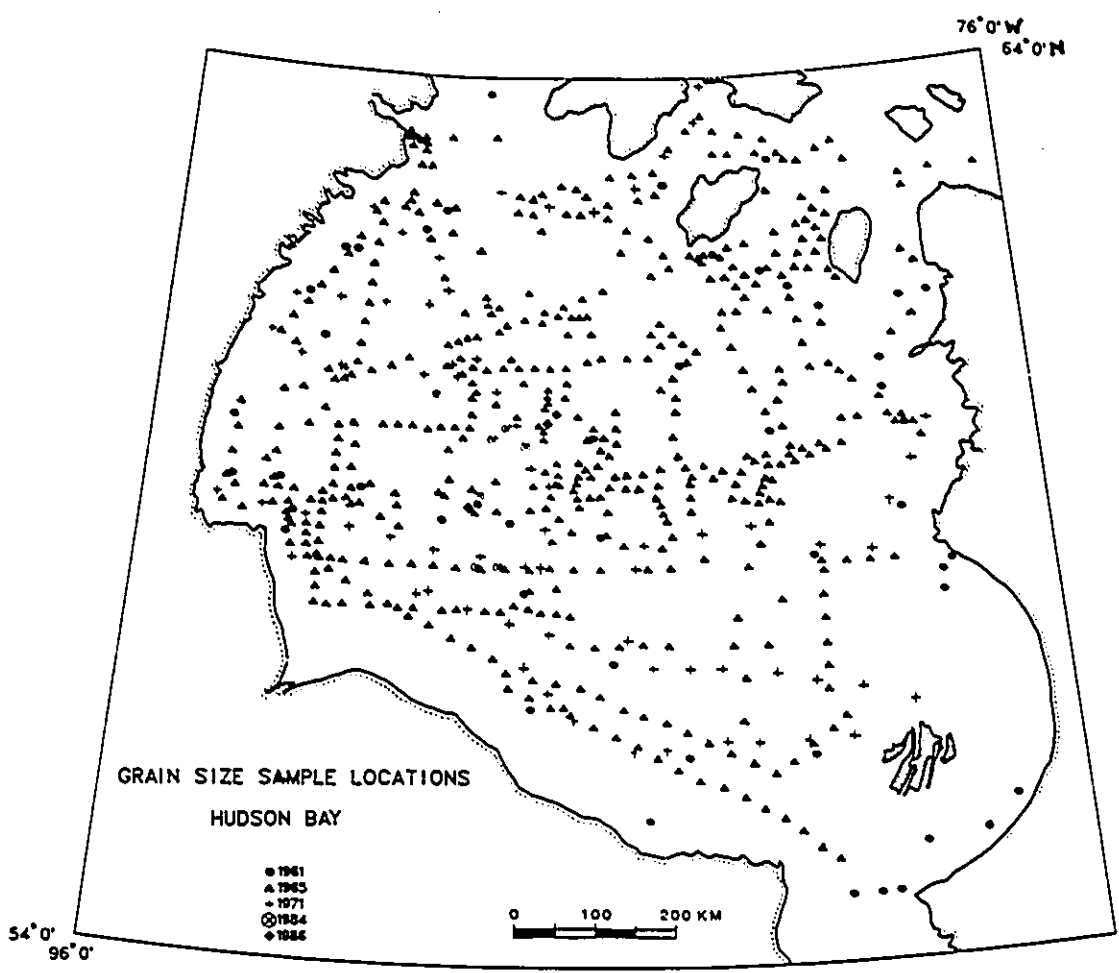


Figure 1.2: Distribution of sample sites in Hudson Bay. Results of textural analyses are available for all plotted locations.

Observations on seabed features and the acoustic character of the sediments were also obtained on geological and geophysical surveys in Hudson Bay (HU 86-040 and HU 87-028). These results complimented the sedimentological and compositional analyses by providing an indication of sediment thickness and the regional distribution of acoustic facies and geomorphic features of the seafloor.

The geological and geophysical survey in Hudson Bay is a joint project involving scientific personnel from both federal and provincial governments as well as universities. Final detailed interpretations of seismic data (Josenhans, AGC) and cores (Henderson, in prep) is currently underway. Preliminary interpretations of selected parts of the data set presented in this thesis, although benefiting from discussions with the scientific staff, are those of the author and are based on shipboard observations and published compilations.

Continuous seismic reflection profiles were collected using the air gun for intermediate penetration (100's of meters) and the Huntec (DTS) deep tow system for shallow (100m) penetration and high resolution ($\pm 0.3m$) (Hutchins et al, 1970). Sidescan sonar data were also obtained using a 70kHz system (750m lateral range) and, less frequently, the 50kHz Klein system (350m lateral range). Navigational positioning for data was by satellite fixing supplemented with dopplar sonar (1986) and log and gyro readings (1987).

In conjunction with the geophysical survey, sediments were sampled, particularly in 1987, using both piston and gravity corers, and the Van Veen grab sampler. Cores were preferentially collected in areas of thick multi-unit sediment accumulation in order to determine the physical characteristics of the units for stratigraphic control and comparison with the acoustic signature of the sediments.

1.4 Regional Setting

Hudson Bay is a shallow marine embayment in northeastern Canada encompassing approximately 637,000km² (Fig. 1.3). It extends approximately 900km north-south (between Cape Henrietta Maria and Southampton Island) and 1000 km at its widest point (between the mouth of the Seal River, Manitoba and Povungnituk, Quebec). The bay joins the Arctic Ocean in the north through Foxe Channel and Foxe Basin and the Atlantic Ocean to the east through Hudson Strait. Southampton, Coats and Mansel Islands form the approximate northeastern limit of the Bay.

The western and southern coast of Hudson Bay is bordered by the District of Keewatin, Manitoba and Ontario. North of Eskimo Point, the Keewatin coastline is generally irregular, low and rocky, lacking soil cover. South of Eskimo Point, and extending into northern Manitoba and Ontario, the coastline is smoother, flatter and heavily drift covered. Onshore areas of northern Manitoba and Ontario are characterized by the flat, muskeg-covered terrane of the Hudson Bay Lowlands (Fig. 1.3). The eastern coast of Hudson Bay is bordered by Nouveau Quebec. South of Cape Smith, a string of small islands parallels the coastline including the Ottawa, Sleepers, Nastapoka and Belcher Groups. Coastal areas are rugged with relief up to 460m and little soil cover.

Hudson Bay is fed by numerous rivers (Fig. 1.3). In the northwest, the Kazan, Thelon and Dubawnt Rivers flow through Baker Lake and Chesterfield Inlet into the Bay. Further south, along the west, southwest and south coast, the Tha-anne, Thlewiaza, Seal, Knife, Churchill, Nelson, Hayes, Severn and Winisk Rivers drain into Hudson Bay. The main rivers on the eastern shore include La Grande Baleine and Nastapoka Rivers. James Bay, the U-shaped basin at the southern end of Hudson Bay, also receives a large input of fresh water from rivers draining the continental interior. The total area of Hudson Bay drainage is approximately 4 million km².

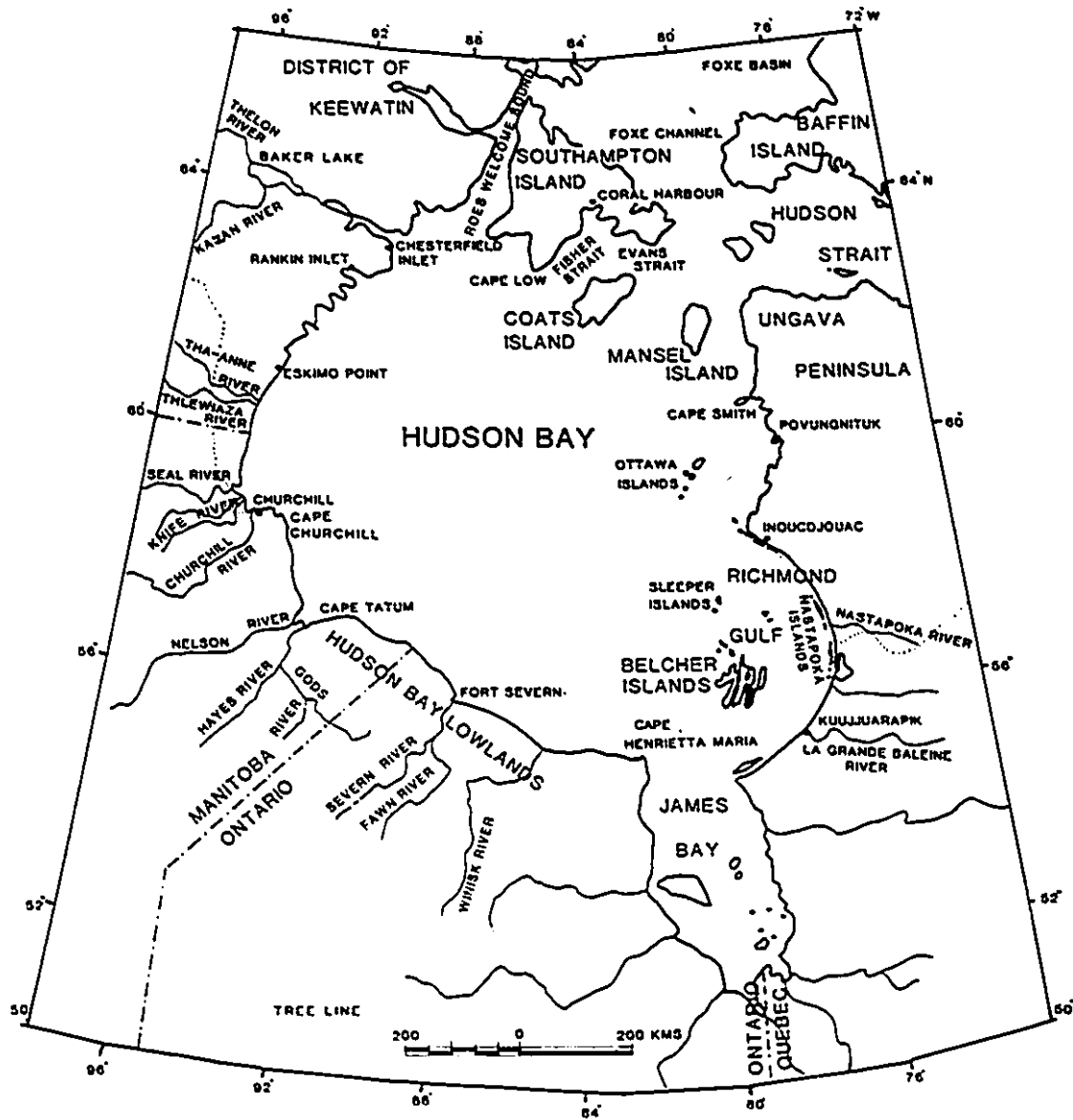


Figure 1.3: Major geographic features of the Hudson Bay region.

1.5 Bathymetry

Hudson Bay forms a shallow basin averaging 100m depth (Leslie, 1964; Pelletier et al, 1968; Pelletier, 1969). Seafloor physiography is dominated by a series of roughly north-south trending ridges and troughs (Fig. 1.4). The Midbay Bank divides the bay into two subequal basins and forms a bathymetric high with depths as little as 40m. The Hudson Basin, to the west of the Midbay Bank, is broad (approximately 250km wide) and up to 250m deep while the Winisk Trough on the east of the Midbay Bank, is much narrower (approximately 80km wide) and reaches a depth of 325m in a channel within the trough (Pelletier, 1969; Pelletier, 1985). These bathymetric depressions merge south of Coats and Mansel Islands forming a channel extending into Hudson Strait (Fig. 1.4).

The sea floor morphology is controlled primarily by the nature and structure of underlying bedrock as interpreted from onshore geological observations (Norris and Sanford, 1969; Sanford et al, 1968) and shallow reflection seismic profiles and echograms (Leslie and Pelletier, 1965; Pelletier, 1969; Grant, 1969; Lewis and Sanford, 1971; Grant and Sanford, 1988). Major ridges and depressions are closely related to erosional characteristics of the bedrock, with recessive formations underlying Hudson Basin and Winisk Trough and ridges composed of the more resistant facies. Cuestas commonly delineate formational boundaries or tectonic features (Sanford and Norris, 1975; Sanford et al, 1979; Norris, 1986).

Pelletier (1969,1985) recognized a radial system of submarine valleys superimposed on the major bathymetric features. He interpreted the valleys as a remnant pre-Pleistocene drainage system although oversteepening of fluvial channels undoubtedly occurred during glaciation. The conclusion is based on observations that valleys extend from the mouths of present rivers in the Hudson Bay Lowlands, converge, grade downward from shoreline to submarine elevations linked to Hudson Strait, and down-cut

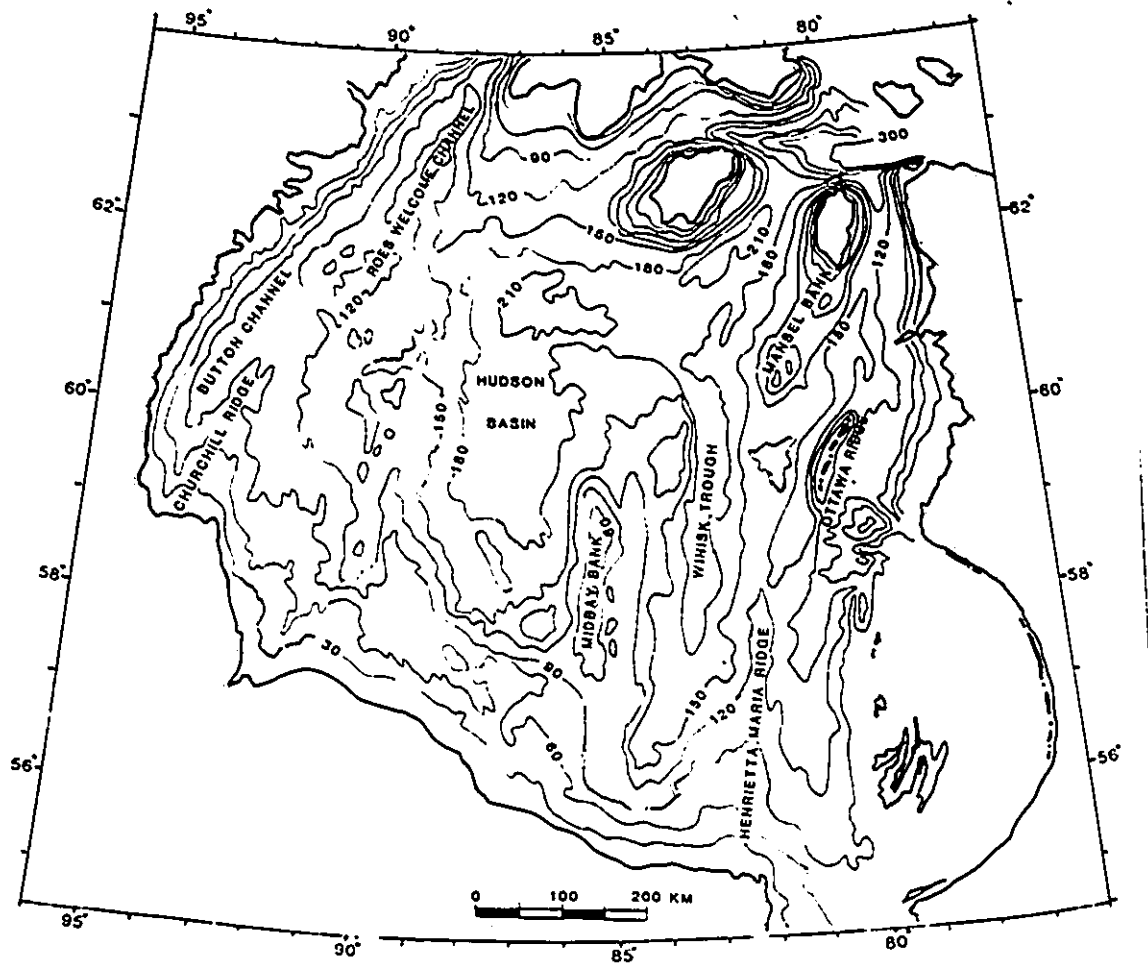


Figure 1.4: Bathymetry of Hudson Bay. Contours are in metres and major physiographic features are indicated (modified from National Hydrographic Service, National Earth Science Series, NP 15-16, 16-17, 17-18).

into underlying bedrock. Josenhans et al (1988) interpreted, presently undated, infilled channels in the Hudson Basin unconformably overlain by scoured sediment as indicative of pre-glacial fluvial erosion.

1.6 Bedrock Geology

Hudson Bay is predominantly underlain by Paleozoic and Mesozoic(?) sedimentary rocks of the Hudson Platform, which also outcrop along the southern coast. Precambrian rocks of the Churchill and Superior tectonic Provinces (Stockwell, 1970) surround and underlie this Paleozoic basin, forming the east and west coastline of the Bay (Fig. 1.5). These two distinctly different geological terranes may be characterized lithologically and mineralogically on the gross scale. The following discussion outlines the geological framework of the area with particular emphasis on the distinctive lithologic aspects of the Shield and Paleozoic terranes.

1.6.1. Shield Terrane

The geology of the Archean rocks of the Superior Province which outcrop along the east coast of Hudson Bay is complex and consists primarily of plutonic and high grade metamorphic rocks with wide variations in texture and composition, ranging from granite to granodiorite (Kretz, 1960; Stevenson, 1968; Goodwin, 1972). The rocks have been metamorphosed to the amphibolite facies which overprints previous granulite metamorphism in places (Herd, 1978; Card and Ciesielski, 1986).

Rocks of the Churchill Province outcropping along the west coast of Hudson Bay consist primarily of granitoid igneous rocks and a variety of gneisses also metamorphosed to granulite and amphibolite facies similar to the Superior Province (Davidson, 1972; Eade, 1978). Within the Churchill Structural Province, however, several distinctive, virtually unmetamorphosed, volcanic-sedimentary associations are present in linear to

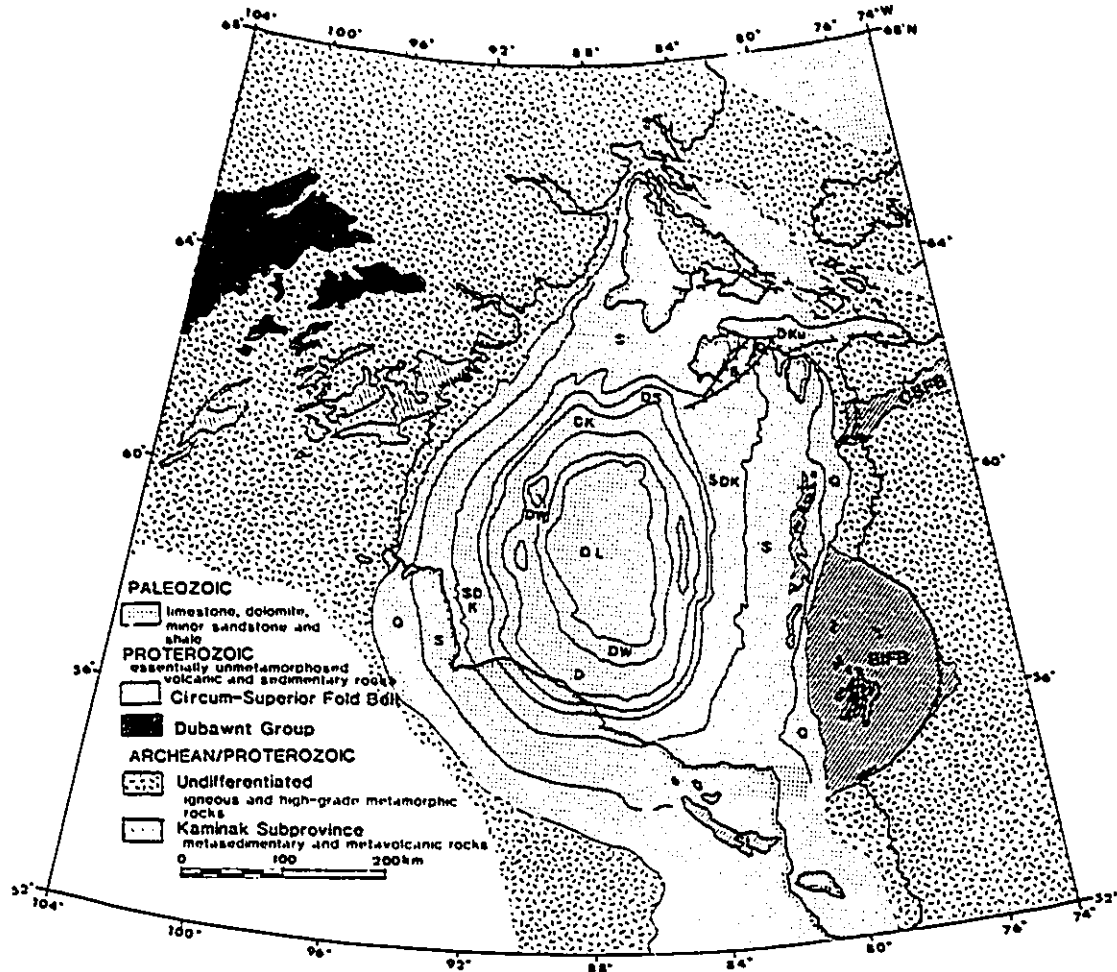


Figure 1.5: Bedrock geology of Hudson Bay region. Designations within the Paleozoic succession include: O, Ordovician formations, undifferentiated; S, Silurian formations, undifferentiated; SDK, Kenogami River Formation; DS, Stopping River Formation; DK, Kwataboheagan Formation; DW, Williams Island Formation; DL, Long Rapids Formation; D, other Devonian formations, undifferentiated; and DKu, Devonian to Cretaceous (?), undivided.

Within the Circum-Superior Fold Belt, designations include: CSFB, Cape Smith Fold Belt; BIFB, Belcher Island Fold Belt; and SI, Sutton Inlier (from Grant and Sanford, 1988).

curvilinear fold belts (Fraser et al, 1978; Donaldson, 1986) and are discussed below:

1) Circum-Superior Fold Belt: The Circum-Superior Belt (Baragar and Scoates, 1981) links Early Proterozoic supracrustal rocks of the Thompson Fold Belt, west of Hudson Bay, with outcrops of the Sutton Inlier exposed on Cape Henrietta Maria and the Belcher and Cape Smith Fold Belts of the east coast of Hudson Bay (Bostock, 1969, 1971; Baragar and Scoates, 1981). Lithologically, the structure is characterized by unmetamorphosed sedimentary and volcanic rocks with associated iron formation, although the relative proportion varies.

Rocks of the Cape Smith Fold Belt on Ungava Peninsula are composed primarily of mafic volcanics intruded by numerous mafic and ultramafic sills (Baragar, 1974; Taylor, 1982). Sediments comprise only 15-20% of the area and consist of metamorphosed argillaceous rocks, although sandstones, carbonates, and minor iron formation are present in a thin strip along the southern margin. Greywacke occurs as discontinuous beds within the volcanic sequence. Pillowed and tholeiitic basalts correlated with volcanics of the Cape Smith Fold Belt were mapped on the Ottawa Islands (Baragar and Lamontagne, 1980).

Further south within the Richmond Gulf and offshore islands, including the Belcher Islands (Jackson, 1960; Dimroth et al, 1970; Ricketts and Donaldson, 1981; Chandler, 1984), sedimentary rocks form a more significant proportion of the succession. The strata consist generally of marine carbonates, immature and mature sandstones, argillites, and basaltic flows and sills with associated iron formations. A >2000m thick turbidite sequence, the Omarolluk Formation, is exposed within the eastern Belcher Islands, a number of the outlying islands including Baker's Dozen and King George Islands, and is interpreted as underlying large parts of the adjacent seafloor (Ricketts and Donaldson, 1981; Jackson, pers. comm., 1987). The formation is characterized primarily by regular tabular-bedded dark green to grey

greywacke and subgreywacke with thinner argillite interbeds. Towards the top of the formation round, concretionary structures become increasingly abundant and the strata become progressively lighter coloured and cleaner (Dimroth et al, 1970). The concretions within the Omarolluk Formation are distinctive and unique and consequently this lithology has been used as a tracer for glacial dispersal as far west as Alberta (Prest and Nielsen, 1987).

Precambrian rock exposed within the Sutton Inlier on Cape Henrietta Maria consists of Archean plutonic and metamorphic rocks overlain by sediments correlated with formations outcropping on the Belcher Islands. These Proterozoic rocks consist of siliceous iron formation, greywacke and siltstone intruded by diabase and gabbro sills (Bostock, 1971). Precambrian sedimentary rocks in the Churchill area include subgreywacke, siltstone and slate with minor quartzite, greywacke and conglomerate and are believed to correlate with the similar rocks of the Sutton Inlier (Bostock, 1969).

2) Kaminak Subprovince: On the west side of Hudson Bay, within the Kaminak Subprovince, Archean (?) greenstone-metasedimentary sequences are exposed near Rankin Inlet metamorphosed in places to low amphibolite grade. These metasediments include argillaceous rocks, both mature and immature sandstones, carbonates, and minor iron formation. Overlying Aphebian sediments of the Hurwitz Group consist predominantly of essentially unmetamorphosed orthoquartzite with minor siltstone, shale, and iron formation although scattered patches of greywacke are present within the outcrop area (Davidson, 1969; 1970; Bell, 1970; Heywood, 1973; Eade, 1974; Fraser, 1983; LeCheminant et al, 1984; Tella et al, 1984). Areally, the outcrop is much less significant than Proterozoic sedimentation on the east side of the bay.

3) Dubawnt Group: The most distinctive and laterally extensive lithologies on the west coast of Hudson Bay are the

unmetamorphosed red to maroon volcanic and sedimentary rocks of the Dubawnt Group outcropping near Baker Lake. The Thelon Formation, the most extensive unit, consists predominantly of white to light grey to reddish brown orthoquartzite containing hematite and volcanic fragments, and a kaolinitic or hematitic cement. The sequence also includes brick-red, reddish brown and pink arkosic sandstones of the Kazan Formation in which grains commonly exhibit iron stained rims, and volcanics of the Christopher Island and Pitz Formation. The volcanics are commonly various shades of red and purple, the latter containing feldspar and/or quartz phenocrysts (Donaldson, 1967; Cecile, 1973; Blake, 1980). Distinctive Dubawnt lithologies present in tills have been used for defining glacial dispersal in the District of Keewatin and Hudson Bay (Shilts et al, 1979; Kaszycki and Shilts, 1979, 1980; Shilts, 1982; Henderson et al, 1987).

1.6.2. Paleozoic Terrane

Paleozoic rocks underlie Hudson Bay and James Bay and outcrop along the southern and western coasts (Sanford et al, 1979) (Fig. 1.5). They consist predominantly of grey, brown, tan to cream and light grey limestone, dolomitic limestone and dolomite with minor clastic units. Textures vary from fine crystalline to fragmental and some formations are richly fossiliferous (Sanford et al, 1968; Norris and Sanford, 1969; Norris, 1986). The most distinctive lithologies include parts of the Kenogami River Formation which consist of evaporites and brick red mudstone, siltstone and sandstone; pink calcareous mudstones of the Williams Island Formation; and red and green shales of the Long Rapids Formation (Sanford and Norris, 1975). The outcrop area of these formations in Hudson Bay has been extrapolated from onshore observations, bathymetry, multi-channel seismic profiling (Grant, 1969; Lewis and Sanford, 1971; Grant and Sanford, 1988) and offshore wells in central Hudson Bay (Sanford and Norris, 1975; Dimian et al, 1983).

Recent geophysical surveys in Hudson Bay (Grant and Sanford, 1988) have recognized a discontinuous unit in Hudson Basin overlying the Paleozoic sequence. Preliminary interpretations suggest the unit is Cretaceous (Grant, pers. comm., 1988). Mesozoic fauna has been identified from the seafloor sediment in this area (Sanford, pers. comm., 1988).

1.7 Quaternary Geology

The Quaternary history of the region is recorded in the stratigraphy, drift compositional trends, striations and landforms preserved in the terrain adjacent to and underlying Hudson Bay. During the last or Wisconsin glaciation (110,000 - 5,000 yr BP; Fulton and Prest, 1987) northern North America was covered by the Laurentide Ice Sheet (Chamberlain, 1895). Although extensive ice sheets covered the area during earlier Pleistocene glaciations, preservation of their deposits is limited to sections exposed along river valleys in the Hudson and James Bay Lowlands. Most surficial features in the area result from the last glacial event. At present, the interpretation of the glacial history is a matter of some controversy.

1.7.1. Quaternary Stratigraphy

Stratigraphic sections in the Hudson and James Bay Lowlands include units attributed to both glacial and nonglacial deposition (Fig. 1.6). The presence of nonglacial sediments between tills at low elevations in these areas indicates that glaciers within Hudson Bay receded enough to allow marine incursion and free drainage of rivers into the bay. Glacier ice remaining in Hudson Bay would block northward drainage and dam a fresh-water body in the lowlands between the drainage divide and the ice margin (MacDonald, 1969).

In the past, correlations have been based on the recognition of a sequence of non-glacial sediments of marine, terrestrial and lacustrine origin known as the Missinaibi Formation (Terasme and Hughes, 1960; Skinner, 1973). Dated at >72,500yr

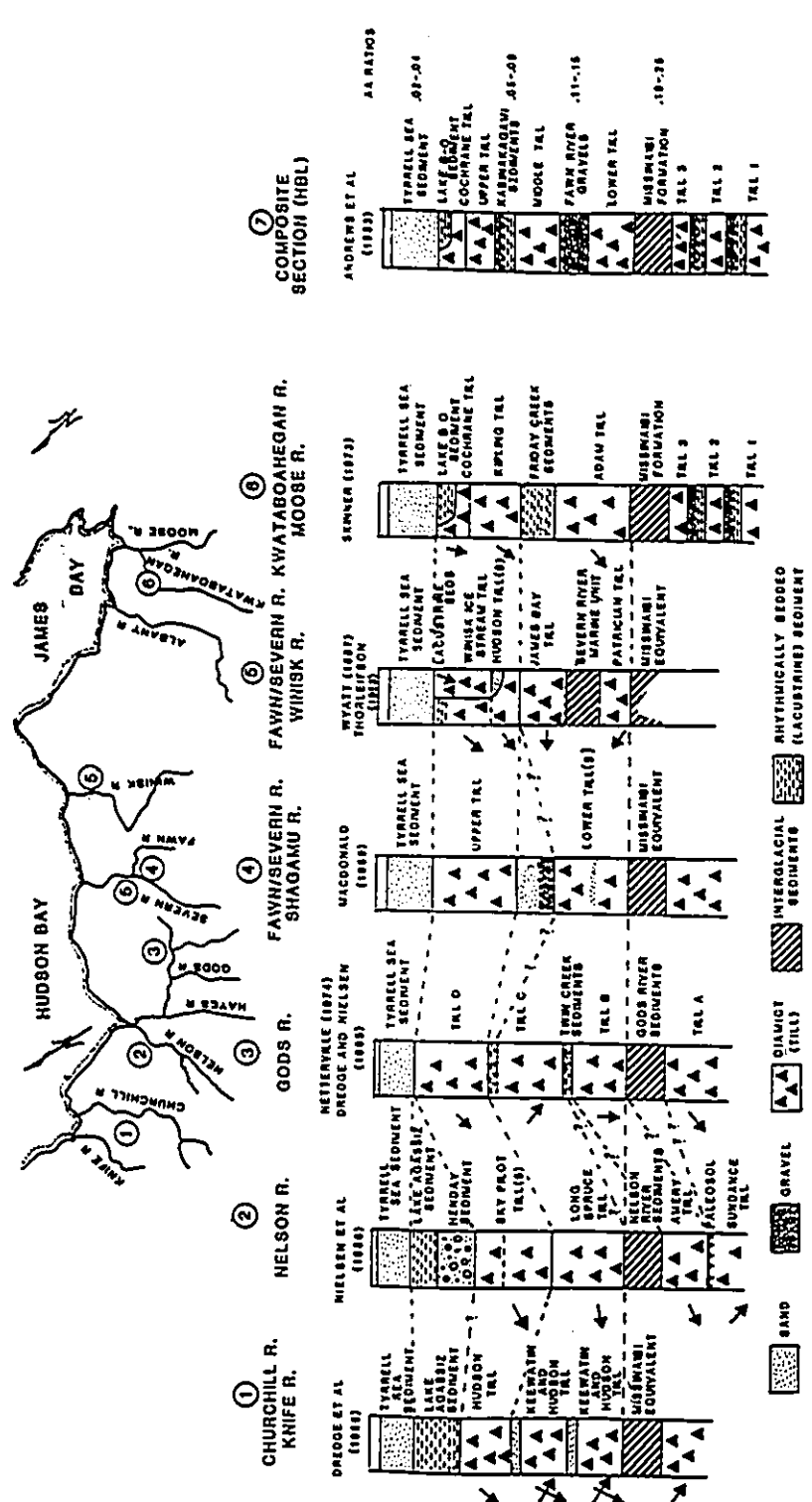


Figure 1.6: Quaternary stratigraphy of Hudson Bay Lowlands. Correlations are tentative. Arrows indicate reported ice flow directions with north oriented towards the top of the page.

using isotope enrichment techniques on wood (Stuiver et al, 1978), the formation is considered to be of last interglacial (Sangamon) age. Making the assumption of complete sediment preservation across the area and lacking reliable dating techniques, similar sedimentary sequences were assumed to be Missinaibi equivalents. Difficulties in interpretation have arisen when several different nonglacial units are preserved.

More recently, amino acid ratios of marine shell fragments incorporated into tills have been used for correlation (Boulton et al, 1982; Andrews et al, 1983; Wyatt, 1987). The ratios of marine shells from Quaternary deposits in the Hudson and James Bay Lowlands, combined with stratigraphic evidence, have led to the conclusion that Hudson Bay was open at least once during the Wisconsin stage (Andrews et al, 1983; Wyatt, 1987) (Fig. 1.6, Section 7). Two till sheets, separated by waterlain sediment, have been recognized overlying the Missinaibi Formation or its equivalent (Fig. 1.6). A third has been postulated based on the interpretation of stratified sediments in the James Bay Lowlands (Kabinakagmi River) below till (Fig. 1.6; Section 7) (Andrews et al, 1983). Similarly, as many as four tills separated by stratified sediments have been recognized below the Missinaibi Formation in the James Bay Lowlands (Terasme and Hughes, 1960; Skinner, 1973; Shilts, 1982, 1985, 1986).

Tentative correlations of composite sections across the Hudson Bay and James Bay Lowlands are shown in Fig. 1.6. The stratigraphic evidence indicates that ice from several shifting dispersal centres covered Hudson Bay during the Wisconsin stage punctuated by periods of development and shrinkage of ice volumes. The last regional ice flow across the area was from the northeast or east. Along the Fawn/Severn and Winisk Rivers and in some parts of the James Bay Lowlands, the regional till is overlain by a brown till (Winisk ice stream till/Cochrane till) deposited by ice flowing south to southeast (out of Hudson Bay) (Fig. 1.6; Sections 5, 6, and 7). These tills contain

lithologies characteristic of bedrock underlying Hudson Bay and have been interpreted as deposits of ice streams or surges from remnant ice masses centered in Hudson Bay (Vincent and Hardy, 1979; Wyatt, 1987; Thorleifson, 1989). Similar ice surges or readvances have occurred in areas to the west (Nielsen et al, 1986; Dredge and Cowan, in press).

1.7.2 Dispersal Trends and Landforms

The distribution of striations and constructive glacial landforms in the District of Keewatin (Lee et al, 1957; Lee, 1959b; Prest et al, 1967; Aylsworth and Shilts, 1985, in press; Shilts and Aylsworth, 1987) and Northern Quebec (Prest et al, 1967; Bouchard and Marcotte, 1986; Gray and Lauriol, 1985) indicates that ice flowed into Hudson Bay from at least two centres: one located in the District of Keewatin (Keewatin Ice Divide), the other in northern Quebec (Nouveau Quebec Ice Divide).

Compositional trends also support ice flow from centres in the District of Keewatin and Northern Quebec. The dispersal pattern of distinctive Proterozoic erratics in the District of Keewatin indicates that ice never flowed onshore north of the Seal River, Manitoba, as suggested by Bird (1953) and Taylor (1956). The size of the dispersal train supports the prolonged existence of an independent centre in the District of Keewatin throughout the Wisconsin Glaciation (Shilts et al, 1979; Shilts, 1980a, 1982). Similar studies in Ungava, Nouveau-Quebec concluded that the east coast was not glaciated by ice flowing out of Hudson Bay (Bouchard and Marcotte, 1986). Eastward transport of glacial erratics from Hudson Bay onto the Ungava shore reported by Lee (1959a) is restricted to areas below the marine limit and has been attributed to deposition by drift ice, not glacial flow (Dionne, 1974).

Ice flow indicators and till composition south of Hudson Bay record the major regional glacial flow towards the west and southwest from an ice centre in Nouveau Quebec (McDonald, 1969;

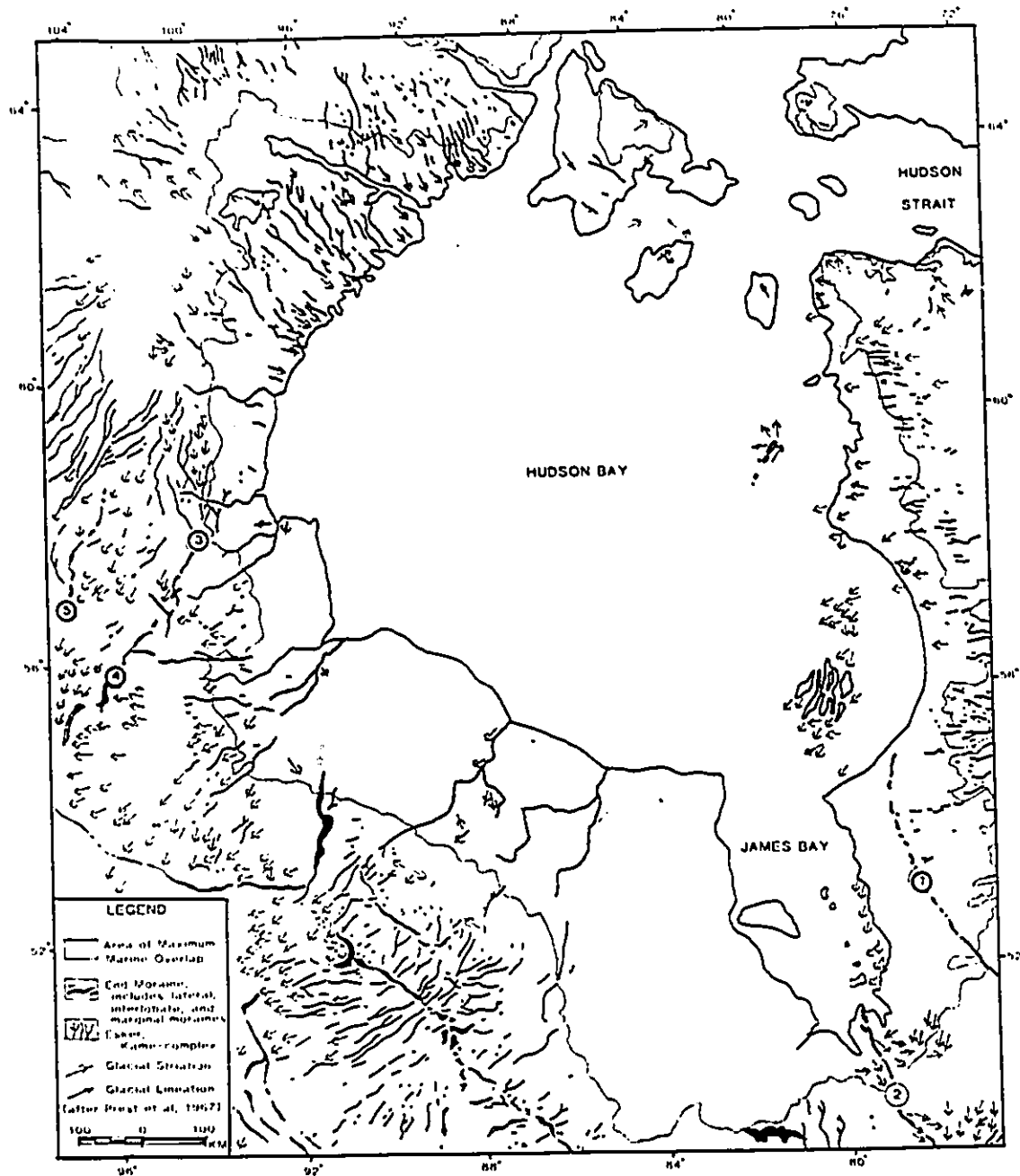


Figure 1.7: Quaternary geology of Hudson Bay region (from Prest et al., 1967). Major moraines are indicated (from east to west): ① Sakami Moraine; ② Harricana Interlobate Moraine; ③ South Knife interlobate moraine; ④ Burntwood-Etawney Moraine; and ⑤ Leaf Rapids interlobate moraine.

Dredge and Nielsen, 1985; Nielsen et al, 1986; Wyatt, 1987; Thorleifson, 1989). The youngest glacial landforms in the area are related to the overlapping, lobate configuration of moraines extending across shield terrane south of the Hudson and James Bay Lowlands, which indicate ice flow south, out of Hudson Bay (Fig. 1.7). The area affected by southward flow is coincident with the extent of carbonate dispersal across the lowlands (Veillette, 1983,1986; Kaszycki and DiLabio, 1986; Henderson et al, 1987).

1.7.3. Deglaciation

Ice recession to centers in the District of Keewatin and Ungava Peninsula is recorded by an extensive system of eskers and ice disintegration features extending radially from these centres (Prest et al, 1967; Prest, 1969; Aylsworth and Shilts, 1985; Shilts and Aylsworth, 1987; Klassen, 1987; Lauriol and Gray, 1987). In northeastern Manitoba, the Leaf Rapids and/or the South Knife and the Burntwood-Etawney moraine systems mark the confluence between west and southwest flowing ice with Hudson Bay/Nouveau Quebec provenance and southward flowing ice from a Keewatin centre (Dredge et al, 1986; Kaszycki and DiLabio, 1986; Dredge, 1983; Klassen, 1983).

South of Hudson Bay, two extensive proglacial lakes were dammed between the major drainage divides and the ice margin as it retreated downgradient. Lake Agassiz covered large areas of Manitoba north of the Hudson Bay-Mississippi River divide (Klassen, 1983) and Lakes Barlow-Ojibway formed between the receding glacier and the Hudson Bay-St. Lawrence River drainage divide (Vincent and Hardy, 1979). The general recession of the ice sheet was marked by localized readvances or surges into the proglacial lakes (Hardy, 1976; Vincent and Hardy, 1979; Dredge and Cowan, in press).

When the ice sheet retreated sufficiently, marine water entered the region through Hudson Strait. Some workers suggest the ice sheet split along the Winisk Trough (Andrews and

Falconer, 1969; Vincent and Hardy, 1979; Dyke et al, 1982). Others postulate splitting over the Midbay Bank (Skinner, 1973) or at the confluence between Keewatin and Nouveau Quebec ice within the Hudson Basin (Prest, 1969, 1984; Denton and Hughes, 1981a; Shilts, 1982). The post-glacial Tyrrell Sea (Lee, 1960) flooded isostatically depressed areas to elevations at least 100 to 300 meters above present sea-level (Fig 1.7).

Proglacial Lake Barlow-Ojibway drained into the Tyrrell Sea at approximately 8100yr BP (Hillaire-Marcel and Occhietti, 1980) grounding the floating margin of Nouveau Quebec ice and forming the Sakami moraine (Fig. 1.7) (Boissonneau, 1966, 1968; Vincent and Hardy, 1979; Hardy, 1976). Skinner (1973), Hillaire-Marcel (1976) and Hardy (1976) inferred this to be a catastrophic event from the presence of an intraformational, clay pebble conglomerate separating glaciolacustrine and marine sediments and the absence of raised beaches between the youngest lacustrine and oldest marine shoreline. Lake Agassiz drained successively and intermittently southward and eastward into the Mississippi and St. Lawrence River and finally northward into the Tyrrell Sea (Klassen, 1983).

Continued isostatic rebound during the Holocene and Recent has exposed large areas of Tyrrell seafloor in coastal regions of Hudson Bay (Aylsworth et al, 1981a-d; Arsenault et al., 1981, 1982; Dredge et al, 1986; Aylsworth and Shilts, 1987a,b). Observations on geomorphic features and sedimentation in these areas provide insights into the sedimentary facies preserved beneath the Bay. In the Hudson and James Bay lowlands, isostatic rebound has also lead to downcutting by rivers, resulting in the erosion of thick Quaternary sections and reworking of the sediment prior to deposition in the bay. A series of raised beaches are present along the shoreline in this area. Coastal uplift continues in the Hudson Bay area although the rate varies across the region. Values of 0.7 to 1.0 m/century have been calculated along Cape Henrietta Maria (Webber et al, 1970).

CHAPTER 2

SEISMIC ANALYSIS AND CORE DESCRIPTIONS

2.1 Introduction

Marine geological surveys were conducted in Hudson Bay aboard the CSS Hudson during October, 1986 (HU 86-040) and August, 1987 (HU 87-028) along the tracks shown in Fig. 2.1. Seafloor morphology, acoustic records, and sediment characteristics indicate that the surficial materials within Hudson Bay and Hudson Strait are primarily Quaternary deposits. Large relict iceberg scours were observed in over 200 m of water and acoustically massive deposits interpreted as diamicton, possibly till, are present as the lowermost units throughout the area.

The purpose of this chapter is twofold: (1) to outline the stratigraphy and distribution of acoustic facies and seafloor features, as interpreted from high-resolution seismic reflection, sidescan sonar records, and core stratigraphy, and (2) to describe the textural and sedimentological variations within cores in order to provide a framework for discussion of the sedimentology of surficial deposits in the bay.

2.2 Acoustic Facies

Seismic facies analysis is used to relate acoustic properties of sediments to lithofacies in order to infer the depositional environment of seafloor sediment. Each acoustic unit is characterized by a seismic signature whose parameters (configuration, amplitude, continuity, frequency, etc) differ from adjacent units or groups of units. The seismic reflections within each unit are interpreted as expressions of certain stratigraphic, lithologic and depositional features of the deposits. Comparison with cores collected along seismic lines indicates that the subbottom profiles closely approximate geologic stratigraphy and may, within limits, be used for the recognition of sedimentary facies and probable depositional

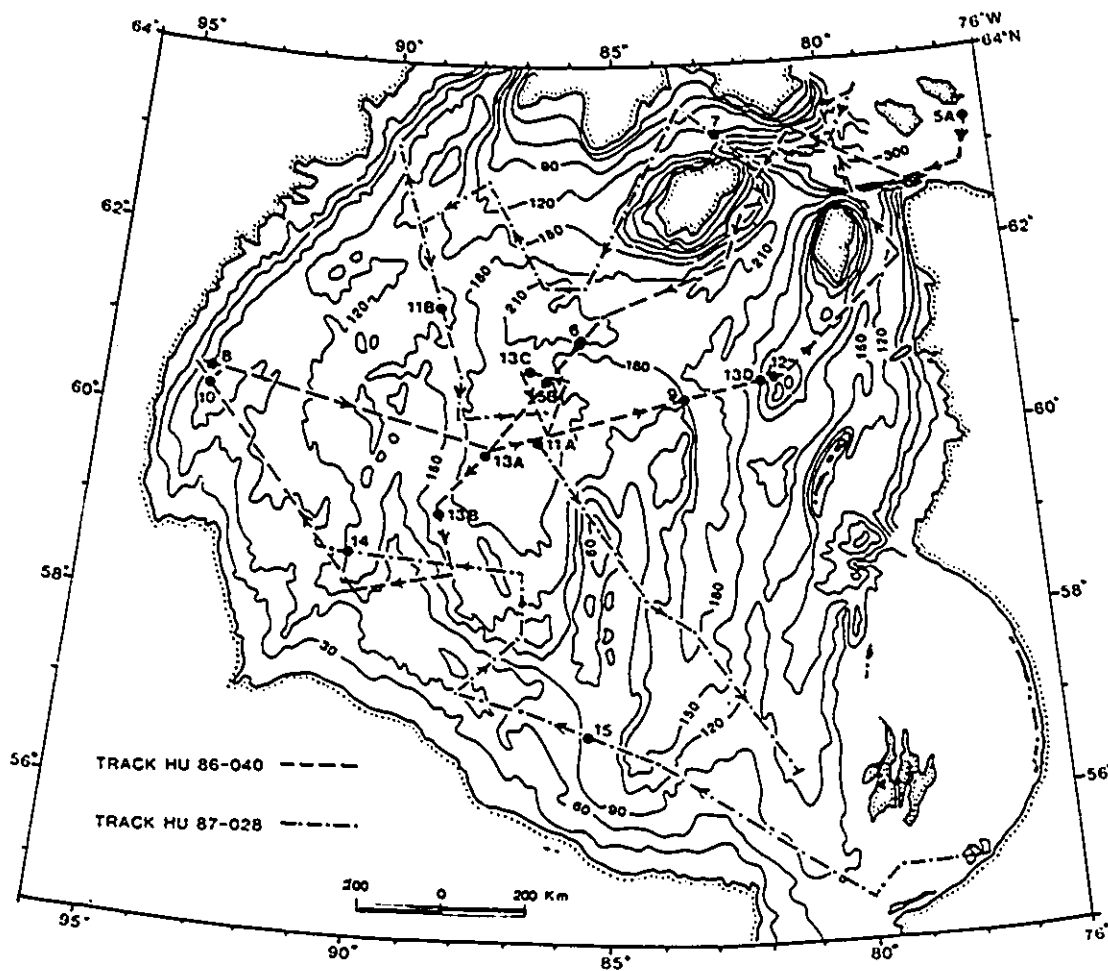


Figure 2.1: Seismic lines from oceanographic surveys in Hudson Bay (HU 86-040 and HU 87-028). The locations of illustrated seismic profiles and sidescan sonar records are indicated by the corresponding figure number.

environments, sediment thicknesses, and post-depositional deformation (Mitchum et al, 1977; Vail et al, 1977).

2.2.1. Description

Quaternary deposits in Hudson Bay and Hudson Strait were interpreted from air gun and Hunttec DTS seismic profiles. Four seismic-stratigraphic facies have been recognized in Hudson Bay and are summarized in Table 1. Preliminary interpretations are based on the relationship between acoustic and sedimentary facies, as documented in cores taken along seismic lines (Fig. 2.2), and investigations of similar geological environments along the continental shelf (Josenhans et al, 1986; Praeg et al, 1986; King and Fader, 1985).

2.2.2 Distribution

The thickness of the surficial sediments and the distribution of facies based on the acoustic characteristics outlined in Table 1 are shown in Fig. 2.3 and 2.4. Interpretative control is based on high resolution Hunttec data (HU 86-040 and HU 87-028) and shallow reflection seismic records collected by the Canadian Hydrographic Service (Josenhans and Zevenhuizen, 1988; Josenhans et al, 1988).

The style of sedimentation varies throughout the area depending on the character of the underlying bedrock surface. Thick sediment accumulations tend to infill depressions in the irregular Precambrian terrane in parts of Hudson Strait and eastern Hudson Bay, including the Richmond Gulf embayment, while sediment overlying flat-lying Paleozoic strata generally forms a thin, irregular cover (Fig. 2.5).

On the regional scale, variation in the thickness of surficial material is related primarily to bathymetry and, secondarily, to proximity to the coast (Fig. 2.3). In Hudson Strait, sedimentary sequences exceeding 120 m are present offshore from the Ungava coast and in the central channel. The stratigraphy in these areas is complex, involving the interre-

TABLE 1: ACOUSTIC FACIES

Acoustic Facies	Reflector Characteristics	Morphology and Occurrence	Interpretation
1	Opaque to limited sub-surface penetration, uniform	-unit restricted to southern part of Hudson Bay offshore from Hudson Bay Lowlands. -poor penetration.	sand, gravel lag deposit (?), marine (?)
2	Semi-transparent to transparent, faintly stratified	-Discontinuous -Restricted to areas offshore from major rivers and within bathymetric lows -Thickness varies, 0-10m. -Uppermost unit when present	Bioturbated or massive mud / marine
3	Parallel, continuous, closely spaced, distinct	-Conformably drapes seafloor, localized -thicker deposits present in Hudson Strait, Winisk Trough, and southern Richmond Gulf Embayment -Overlies Facies 4	Stratified silt and clay / ice proximal glaci-marine or glaci-lacustrine
4	Uniform, dense unstratified	-Thin continuous sheet or lense-shaped body -Up to 5 units may be superimposed in bedrock basins -May form a single or series of ridges up to 30m high -Thickness 1-55m -Smooth basal contact with generally hummocky or scoured upper surface -Distributed throughout the bay and basal unit in Hudson Strait.	Diamict/Till

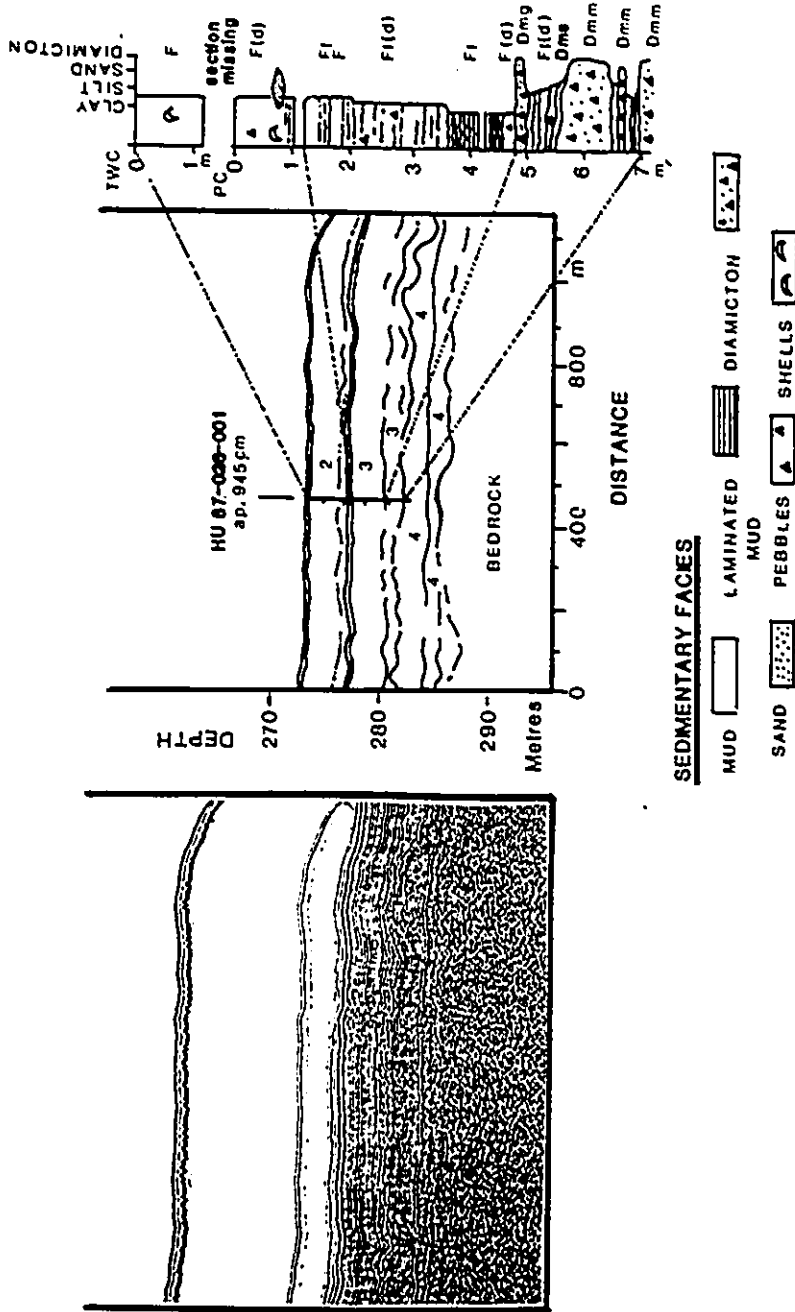


Figure 2.2: Relationship between sedimentary and acoustic facies at site of core HU-87-028-001. Acoustic facies are described in Table 1; sedimentary facies in Appendix B. The apparent penetration (ap.) of the piston core (PC) is 945cm, but only 723cm of sediment was recovered due to incomplete sampling of the upper unit. TWC: trigger weight core.

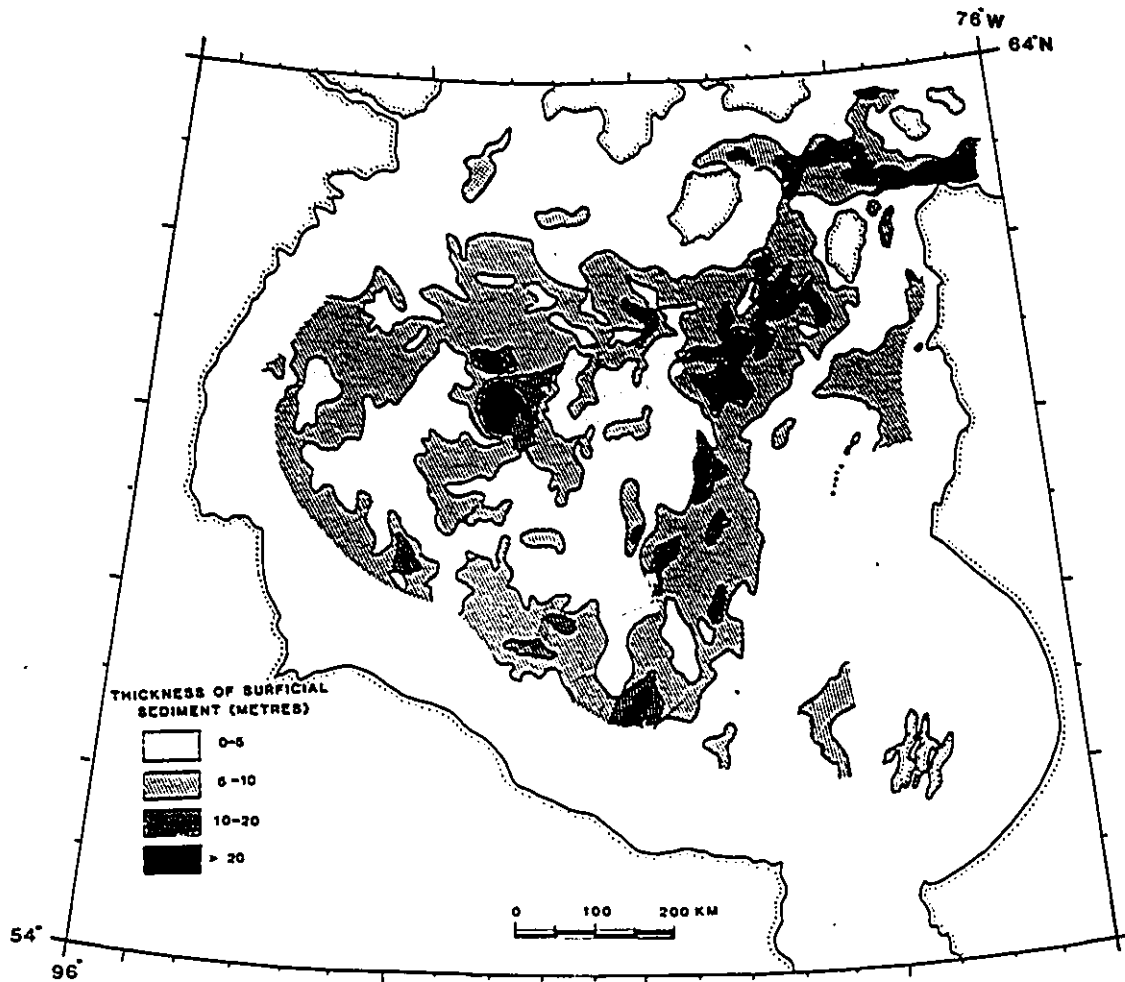


Figure 2.3: Thickness of surficial sediment, Hudson Bay (from Josenhans et al, 1988).

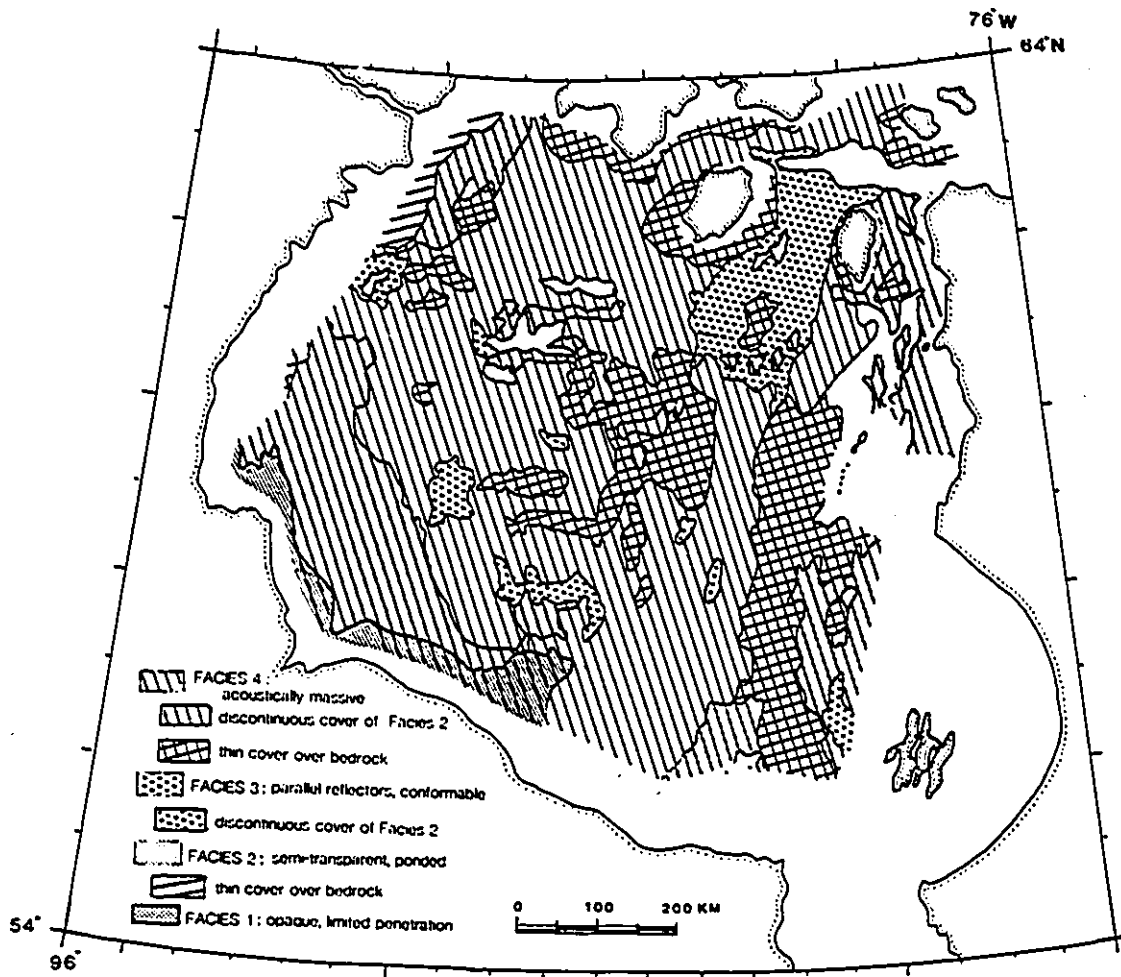


Figure 2.4: Distribution of acoustic facies, Hudson Bay (modified from Josenhans et al, 1988).

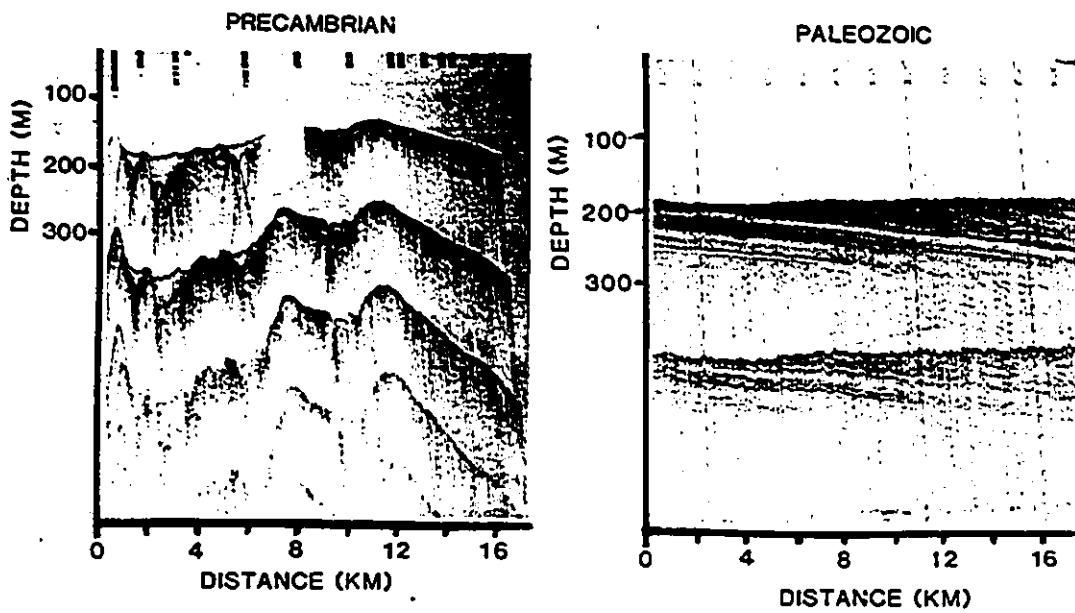


Figure 2.5: Variation in style of sedimentation over Precambrian and Paleozoic bedrock surface.

lationship of several acoustic facies (MacLean et al, 1986; Josenhans et al, 1988).

In Hudson Bay, there are few locations where sediment thickness exceeds 10 m. The surficial material is largely acoustically unstratified and occurs generally as a thin deposit (<7 m) distributed in isolated patchy accumulations on the Paleozoic bedrock surface (Fig. 2.6). In large areas of the Bay, the upper 2-5 m of sediment is intensely scoured and reworked by icebergs (Fig. 2.7). Material subjected to deformation of this type has been referred to as an iceberg turbate (Vorren et al, 1983) because of the difficulties in facies interpretation imposed by partial or complete disruption of the acoustic signature.

Localized sediment accumulations (>20 m thick) are present in ridges, interpreted as morainic deposits (Fig. 2.8), or infilling depressions in the bedrock surface. Recognized basin fill sequences include two to as many as five overlying acoustically massive (till?) units separated by internal reflectors. These may represent the only deposits from earlier glaciations of the bay. Significant accumulations of acoustically stratified material interpreted as glaciomarine sediment are also restricted to bathymetric low areas, particularly the channel between Coats and Mansel Islands, the northern part of the Winisk Trough (Fig. 2.9), and the southern Richmond Gulf area (not shown on figures).

Throughout the entire area, post-glacial sedimentation is minimal with significant accumulations restricted to coastal regions, particularly areas adjacent to the mouths of major rivers. In shallow coastal areas (<90 m), the acoustically transparent facies forms a discontinuous cover, infilling depressions in the glacially modified or bedrock surface (Fig. 2.10). In central Hudson Bay, the recognition of post-glacial sediment is restricted to bathymetric lows (Fig. 2.4).

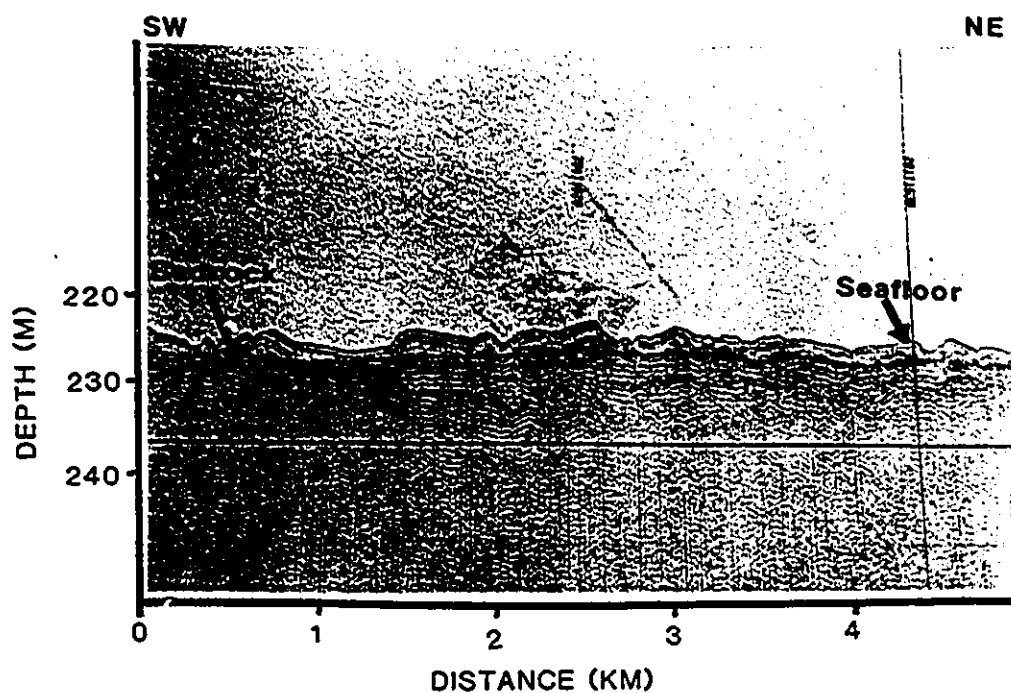


Figure 2.6: Huntce sub-bottom profile showing thin sediment cover over Paleozoic bedrock, central Hudson Bay. Seafloor surface scoured by icebergs. Note lack of post-glacial sediment infill in troughs.

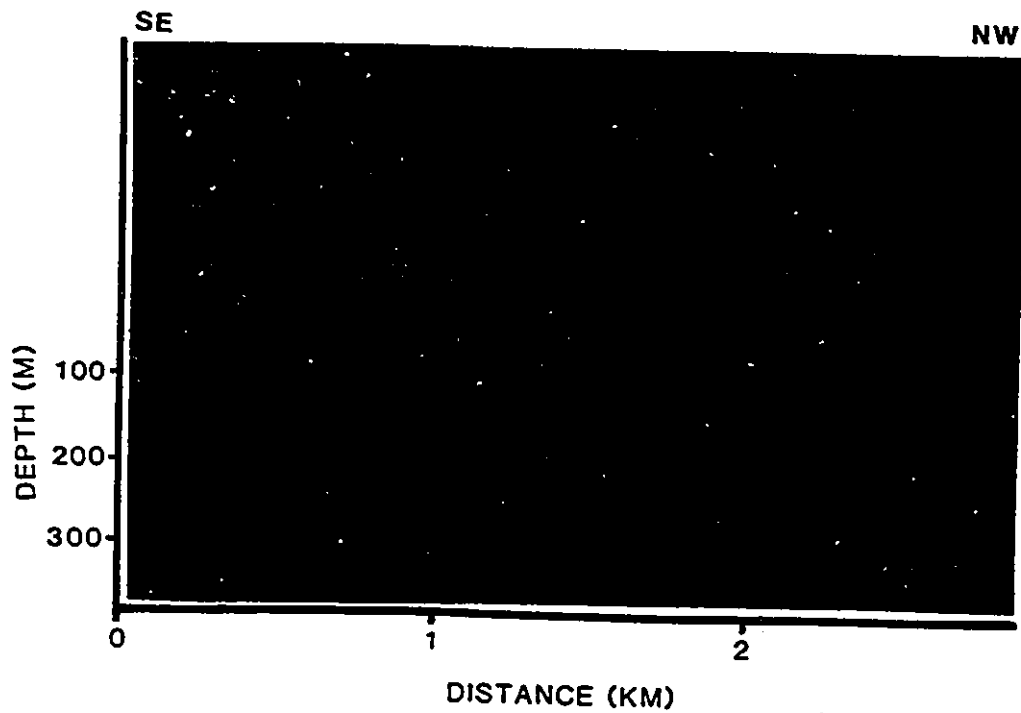


Figure 2.7: Hunttec sub-bottom profile showing effects of iceberg scour on the acoustic response of the sediment. Assuming continuous deposition of the acoustically laminated unit, the seismic signature on the right-hand side of the photo appears to be partially to completely obliterated by scouring.

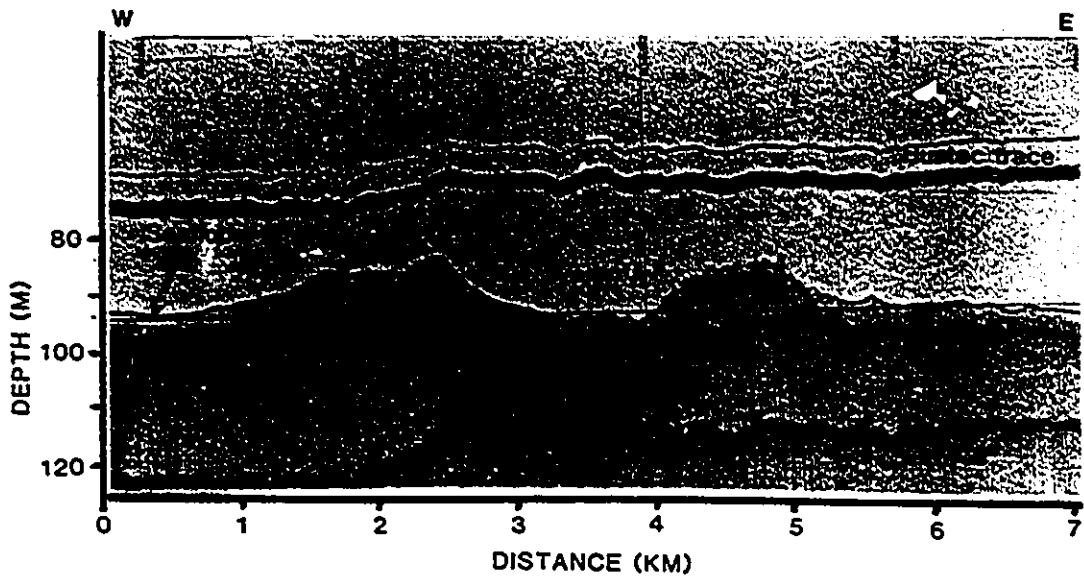


Figure 2.8: Huntce sub-bottom profile of large asymmetric moraines offshore from the District of Keewatin.

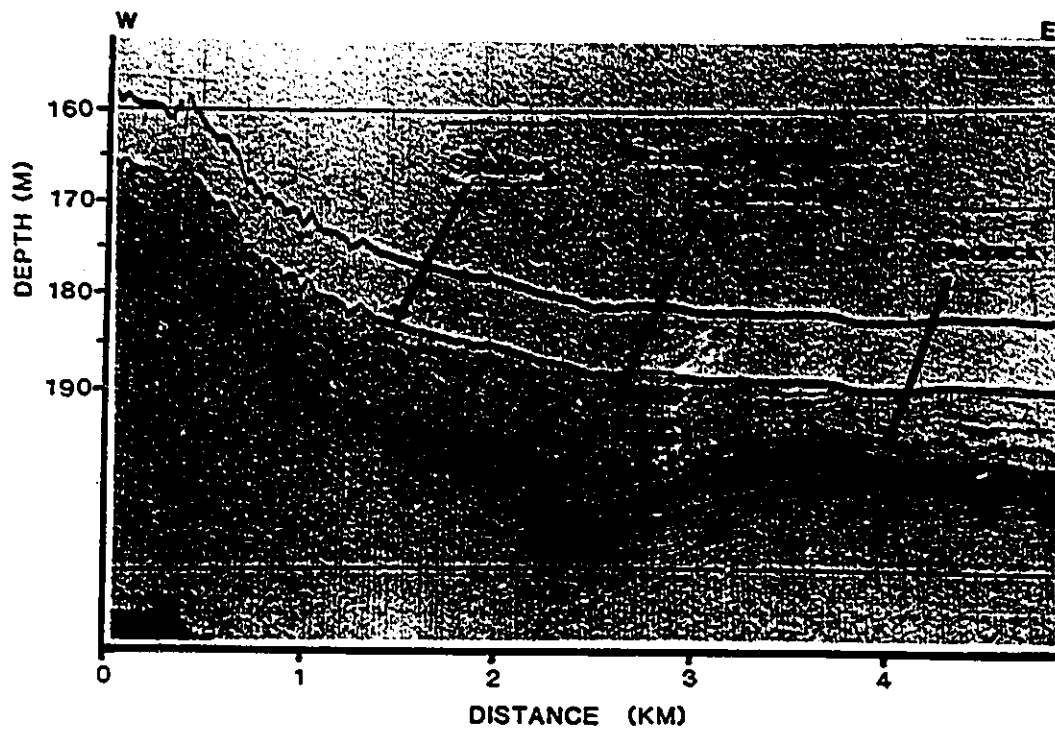


Figure 2.9: Hunttec profile showing sedimentation in the Winisk Trough. Lower limit of iceberg scour is approximately 180m. Trough infill includes a unit with disorganized internal reflectors, possibly representing a till or till flow, and a unit showing continuous parallel reflectors, ice-proximal glaciomarine sediment (?).

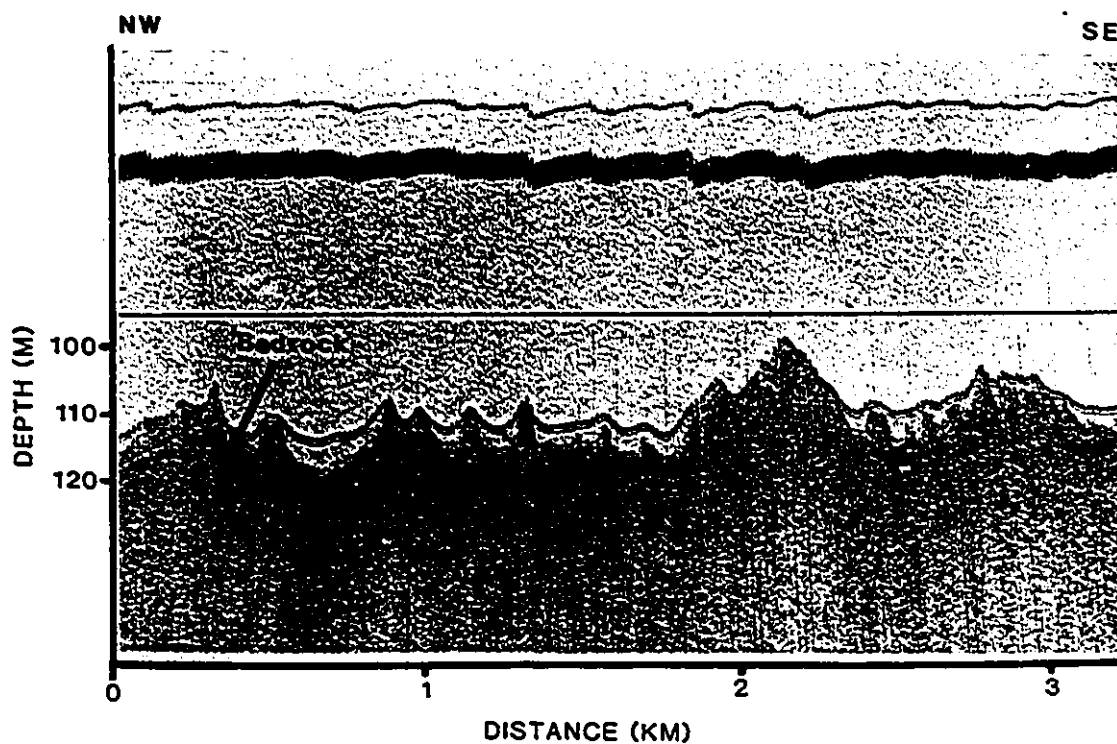


Figure 2.10: Hunttec profile showing post-glacial sediment infill, southwestern Hudson Bay. Ridges have the acoustic character of till and may represent De Geer and/or other moraines.

2.3. Acoustic Geomorphic Features

2.3.1. Description

Large-scale features were recognized on the seafloor from sidescan profiles along track lines (HU 86-040 and HU 87-028) (Fig. 2.1) and extending 750 m on either side. In general, the features appear fairly fresh, lacking sediment infill. As with the Hunttec data, preliminary interpretations are based on observations from similar environments where sampling and submersible observations are extensive and on comparison with aerial photographs of glacial features observed onshore, particularly in areas below marine limit. Recognized features can be attributed to both depositional and erosional forms of subglacial, ice marginal and post-glacial processes.

Subglacial Features

Parallel to subparallel, low linear ridges (2-3 m high) separated by shallow troughs have been recognized on the surface of acoustically unstratified (till?) material overlying a smooth basal unconformity. They are regionally extensive, covering broad areas of the seafloor (10's of km) and occur in association with "corduroy" features (Whittaker et al, 1985; Josenhans et al, 1988) (Fig. 2.11a). Corduroy features range from 100 to 500 m in width and consist of regularly spaced, parallel, straight to curved ribs oriented transverse, either perpendicular or at an angle (generally 45°), to the major trend (Fig. 2.11b).

The linear ridges and transverse (corduroy) bedforms are interpreted as forming at the glacier sole based primarily on the extreme parallelism, lack of relief and morphologic similarity to glacially fluted terrane observed in areas of the District of Keewatin adjacent to Hudson Bay, in places, below marine limit (Prest, 1983, pg. 56; Shilts and Aylsworth, 1987, pg. 141; Josenhans and Zevenhuisen, 1988; Aylsworth and Shilts, in press). The "corduroy" features resemble ribbed (rogen)

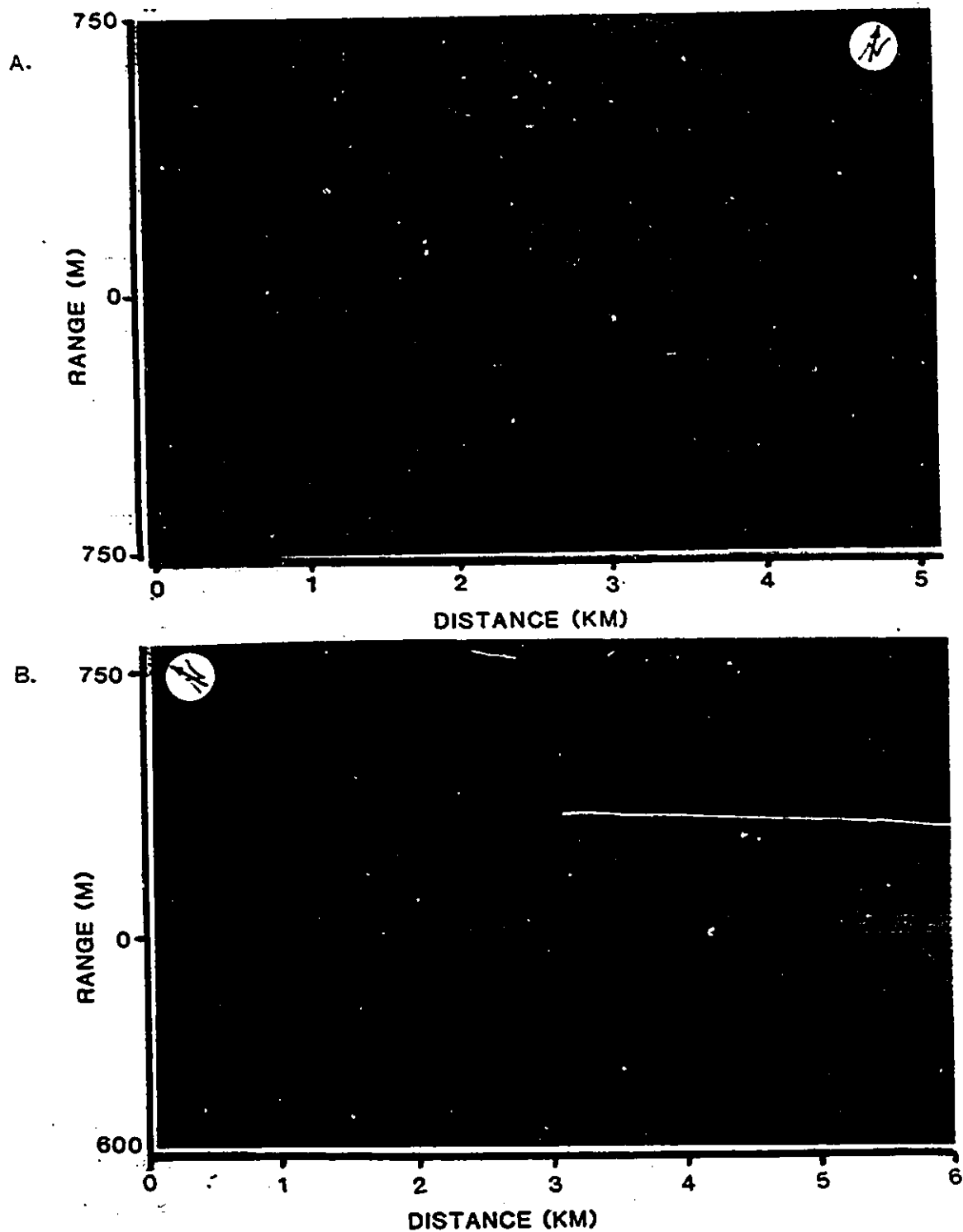


Figure 2.11: Sidescan sonograph of glacial flutings and/or corduroy features.

A. Central Hudson Bay

B. Northwestern Hudson Bay

moraine developed in association with glacial flutings (Josenhans and Zevenhuisen, 1988).

Similar bedforms, however, may be developed by other mechanisms. Josenhans et al (1988) suggest formation of "corduroy" features through vertical movements of a buoyant glacier margin in response to tidal fluctuations. Other workers have suggested formation by icebergs due to unstable rocking motions of the ice keel or, in stiff sediment, due to the formation of fracture blocks (Bass and Woodworth-Lynas, 1988). Although iceberg scour may account for isolated occurrences of "corduroy" features in Hudson Bay, the main concentrations are restricted to specific areas in association with glacial flutings and, therefore, a subglacial origin is the preferred interpretation.

Sediment accumulations in certain unscoured areas within the bay have also been interpreted as possible subglacial deposits formed during disintegration of a late ice cover (Josenhans et al, 1988, pg. 283, 285). Sidescan and Huntec profiles indicate a mottled, hummocky, irregular surface developed on a veneer of acoustically unstratified material interpreted as diamicton (Fig. 2.12). Lack of scour in these areas, despite depths well within the limit of iceberg scour in the bay, suggests that a protective ice cover may have remained during the deglacial scouring phase. The seafloor morphology is somewhat similar to the disorganized till plain characteristic of dead ice topography onshore in the vicinity of the Keewatin Ice Divide (Shilts and Aylsworth, 1987; p.131). Elsewhere in the bay, unscoured seafloor is characterized by a featureless to faintly patterned, slightly hummocky aspect.

Ice Marginal Features

Features interpreted as ice-marginal deposits consist predominantly of asymmetric ridges or thick accumulations of acoustically unstratified material (Fig. 2.8). A series of parallel trending ridges up to 10 m high offshore from the Keewatin coast (Fig. 2.10) and in northeastern Hudson Bay,

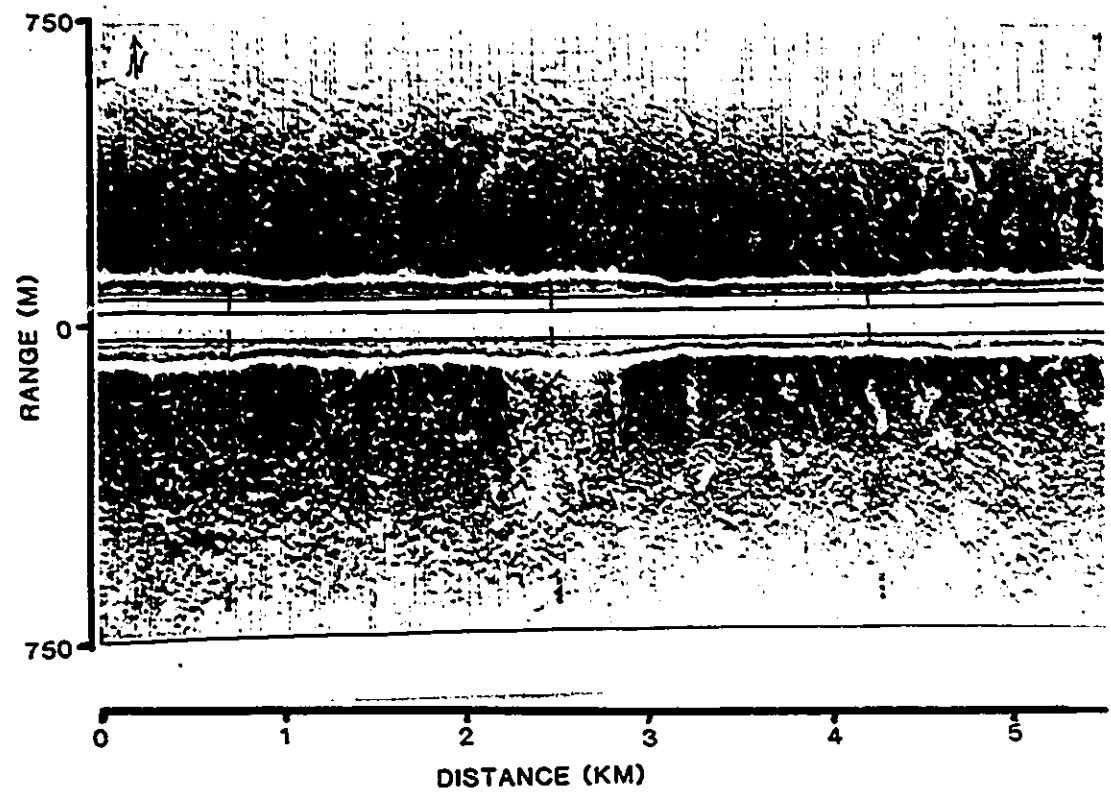


Figure 2.12: Sidescan sonograph showing unscoured mottled seafloor on Mansel Bank, northeastern Hudson Bay.

between Mansel Island and the Ungava Peninsula, have been interpreted as De Geer moraines based on morphology (Josenhans et al, 1988). The scoured surface of these deposits precludes formation by modern marine processes such as tidal currents.

Post-glacial Features

A variety of grooves and furrows were observed and interpreted as iceberg scours formed by the ploughing of iceberg keels across the seafloor (Josenhans et al, 1988). Since modern icebergs are absent in the bay, these features were undoubtedly formed during deglaciation. Scour types and acoustic characteristics are outlined in Table 2 and Fig. 2.13. Morphologies depend on the size and shape of the icebergs, physical properties of the seafloor sediment and the driving force of ice motion and, consequently, have implications for the nature of the break-up of the Wisconsin ice-sheet.

Other, presumably post-glacial, features have been observed locally within the bay. Linear faults and/or slumps involving thick accumulations of acoustically stratified and/or transparent sediment were recognized in the Richmond Gulf area. Large-scale sand waves cut by iceberg scours (Fig.2.14) north of the mouth of the Nelson River have been observed and cored. Channels are present cutting through acoustically unstratified sediment interpreted as diamicton (Fig. 2.15). Erosion appears to post-date till deposition but whether the channels were formed during or following glaciation cannot be determined.

2.3.2. Distribution

The orientation and distribution of geomorphic features is shown in Figure 2.16. Regionally extensive areas are dominated by glacially fluted, unscoured and iceberg scoured terrane. To a large extent, the distribution of these features appears to be restricted to specific zones which are related, in part, to bathymetry as indicated in an E-W transect across the central and southeastern parts of the bay (Fig. 2.17). The distribution and relationship between these features is important in

Table 2

ICEBERG SCOUR TYPES

Sonograph Characteristics	Huntec Characteristics	Interpretation
<ul style="list-style-type: none"> -Broad, flat bottomed depressions, -50-300m wide, -circular to elliptical configuration with long axis oriented N-S, -commonly appears as series of overlapping arcs, -several complete circles present. 	<ul style="list-style-type: none"> -Rounded, bulbous, patchy sediment accumulations, -0-5m thick, -basal contact sharp and straight, -acoustically unstratified, -commonly underlain by bedrock or sediment interpreted as till. 	<ul style="list-style-type: none"> Arcuate iceberg scour
<ul style="list-style-type: none"> -Wide, flat bottomed depression, ->200m wide, -linear, -internal furrows commonly parallel long axis of feature. 	<ul style="list-style-type: none"> -as above 	<ul style="list-style-type: none"> Wide, linear, iceberg scour
<ul style="list-style-type: none"> -Broad, flat bottomed, linear depression, -<50m wide, -subparallel, -closely spaced. 	<ul style="list-style-type: none"> -Undulating surface, -relief 2-3m, -berms may be developed, -acoustically unstratified. 	<ul style="list-style-type: none"> Parallel to subparallel iceberg scour
<ul style="list-style-type: none"> -V-shaped and flat bottomed in cross section, -straight to slightly curved, -subparallel to random orientation, -narrow (25-100m wide) 	<ul style="list-style-type: none"> -Generally shallow relief <3m -slightly rounded to sharp trough, -narrow -well established berms, -acoustically unstratified. 	<ul style="list-style-type: none"> Normal iceberg scour

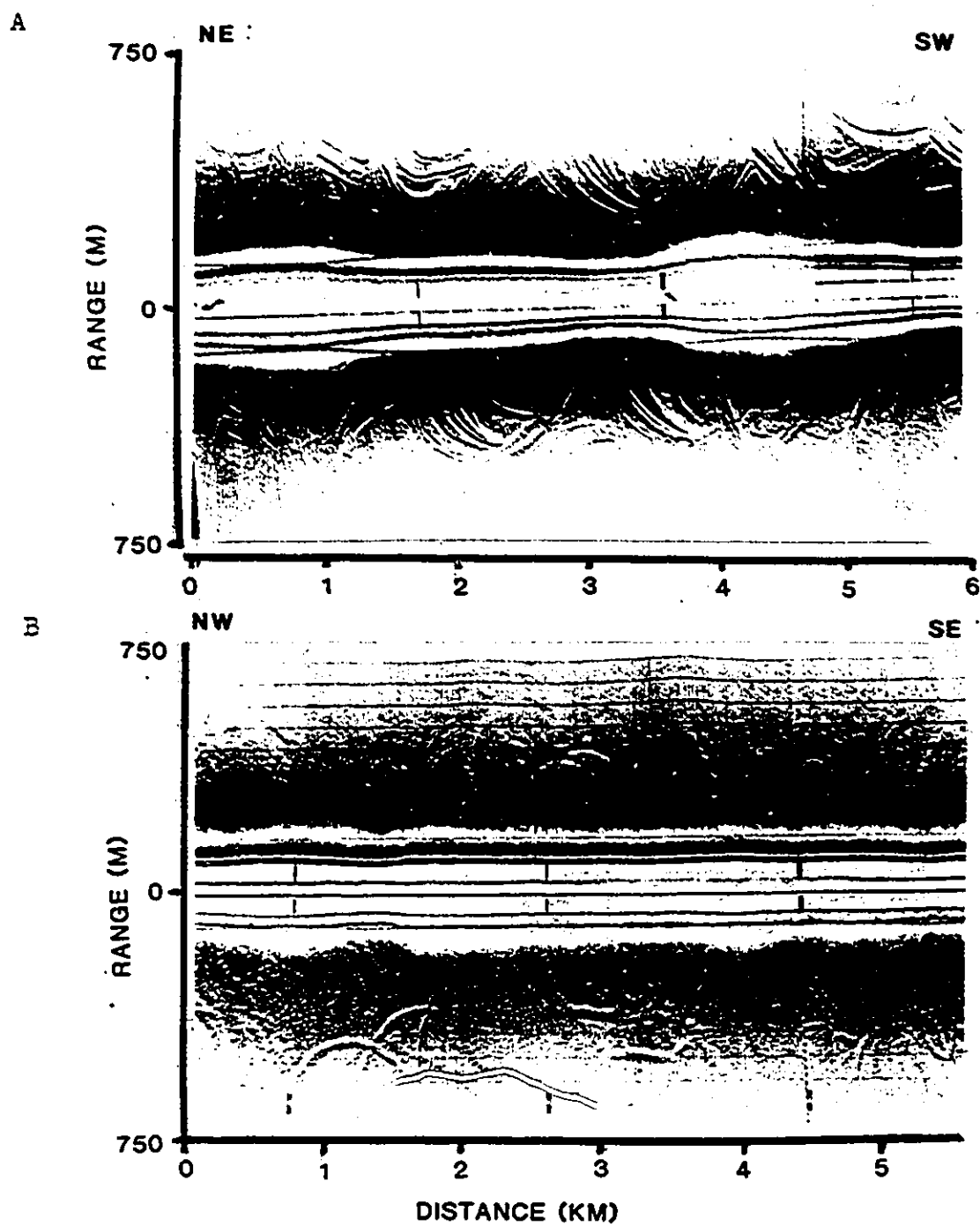


Figure 2.13: Sidescan sonographs showing iceberg scour types.
 A. Large arcuate scour.
 B. Arcuate scour cut by wide linear scour in central Hudson Bay.

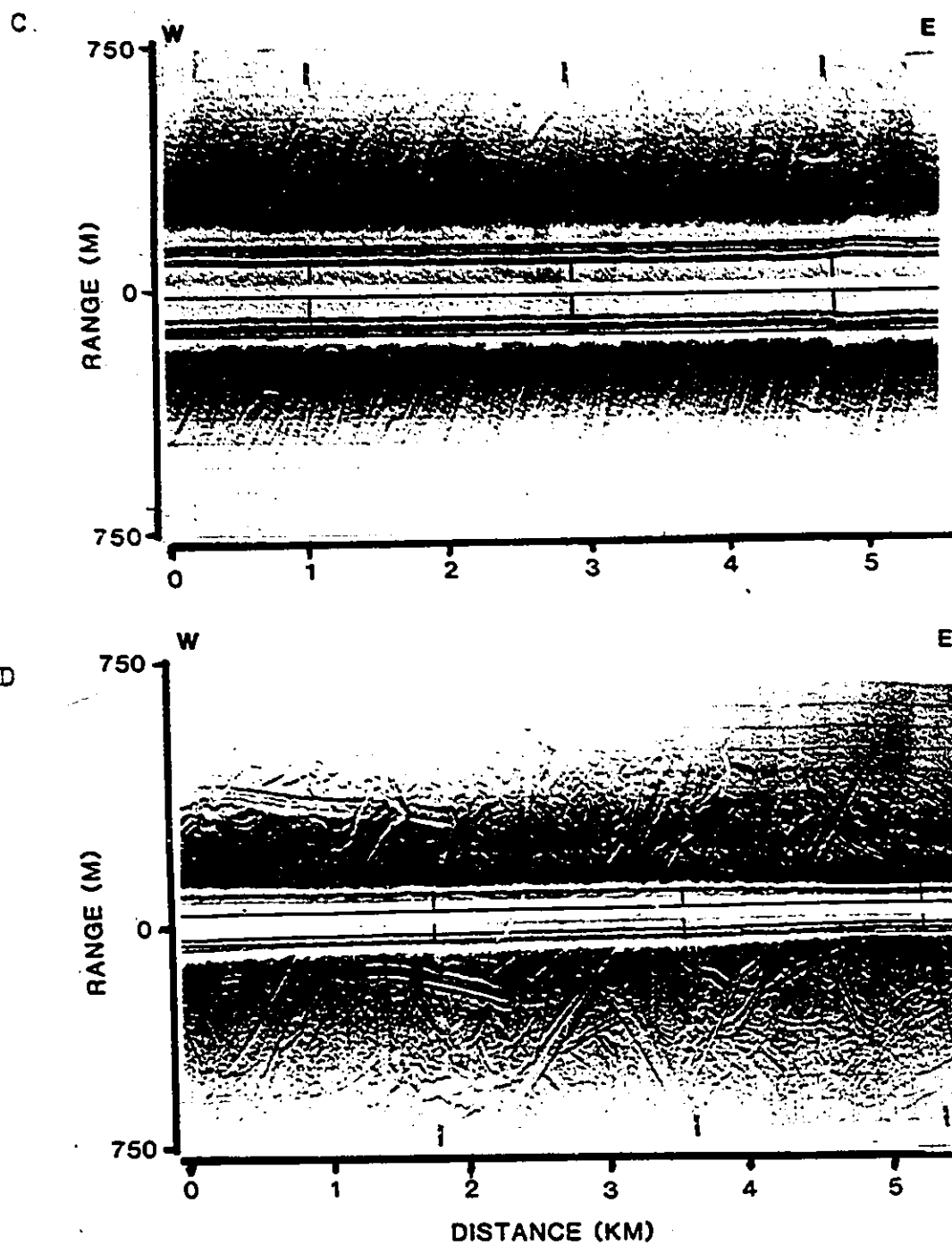


Figure 2.13 (cont'd):

C. Parallel to subparallel scour.

D. Random iceberg scour.

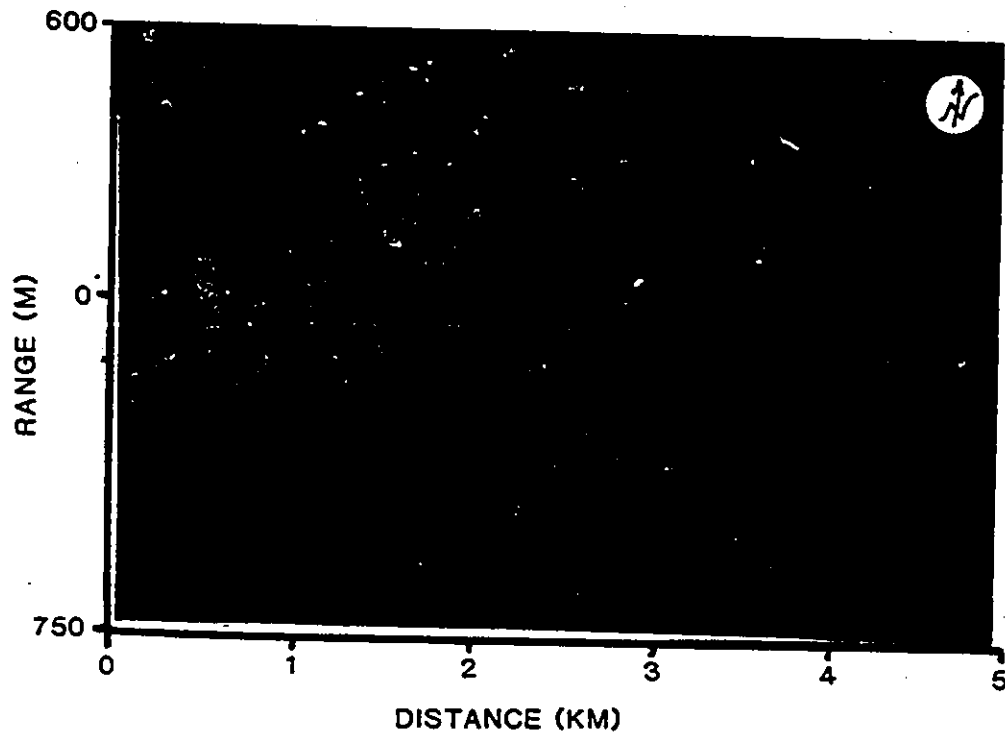


Figure 2.14: Sidescan sonograph of bedforms, interpreted as sand waves, offshore from the Nelson River Estuary. These features have been cored (HU 87-028-090). Note that the surface is scoured by icebergs.

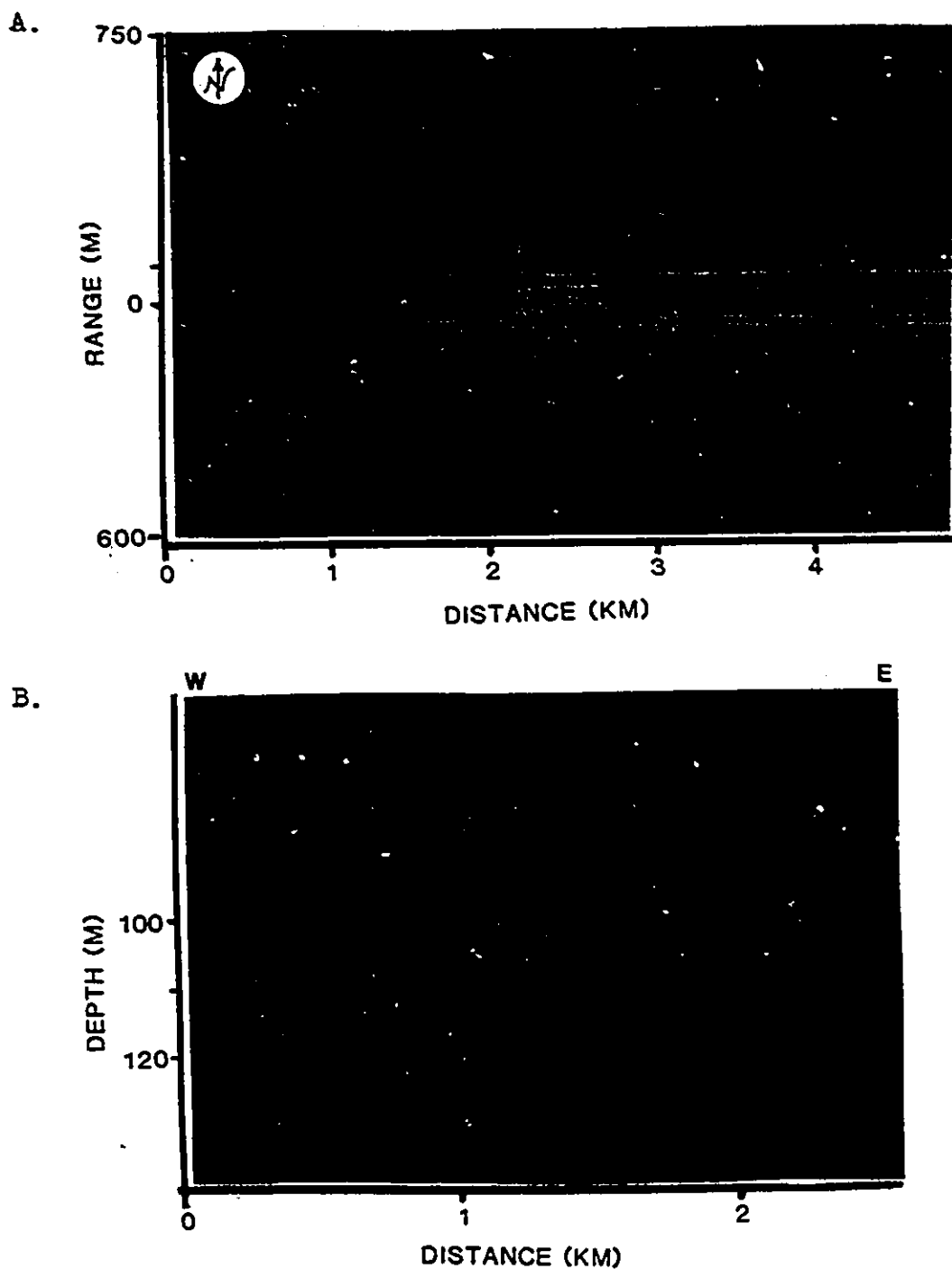


Figure 2.15: Channels in southern Winisk Trough.
A. Sidescan sonograph showing extent of channel feature.
B. Huntec sub-bottom profile from same area. Channel appears to have eroded glacial deposits. No post-glacial sedimentation is recognized.

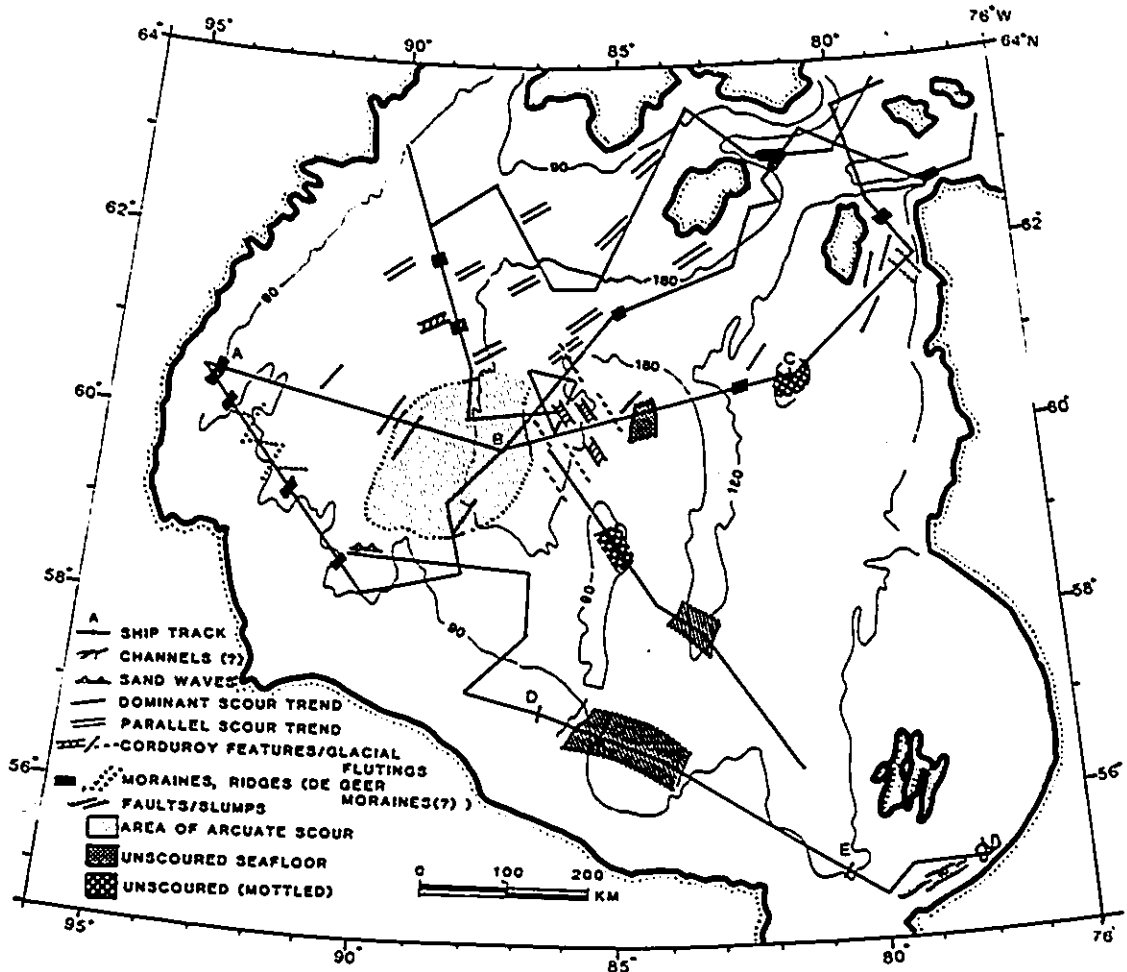


Figure 2.16: Distribution of seafloor geomorphic features, Hudson Bay. (modified from Josenhans et al, 1988)

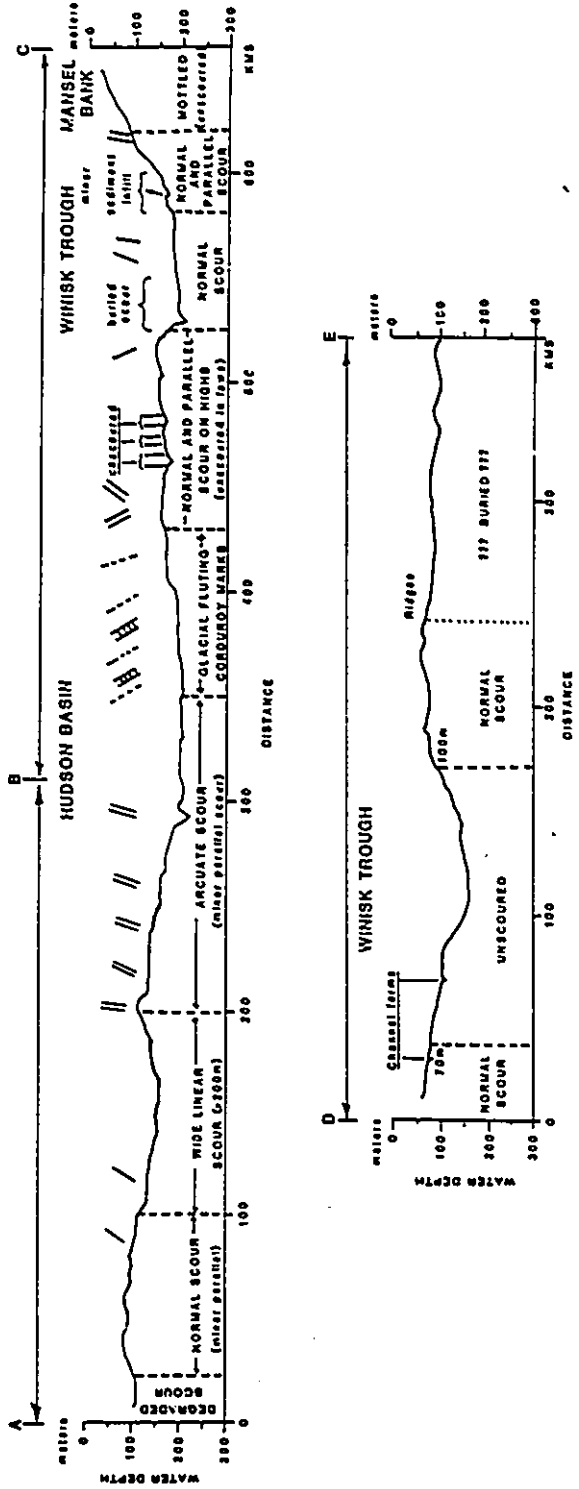


Figure 2.17: Relationship between bathymetry and distribution of seafloor features. Symbols for iceberg scours, glacial flutings and other seafloor geomorphic features and profile locations across central and southern are indicated in Fig. 2.16. (modified from Josenhans et al, 1988)

assessing the extent of sediment modification by iceberg scouring and also has implications for the nature of deglaciation of Hudson Bay.

2.3.3. Interpretation

The oldest feature appears to be the glacially fluted seafloor which is cut, in one location, by arcuate scour marks. The relatively younger arcuate scours are confined to an area in the central and western portion of Hudson Basin in water up to 200 m depth (Fig. 2.16 and 2.17). Within this zone, no area is left unscoured. The eastern portion of the Hudson Basin lacks scour and the presence of the subglacial features (fluted/corduroy terrane) in this area suggests some protection by glacial ice cover during the arcuate scour event. Because of the limited extent of the arcuate scours within the central and deeper part of the bay, the margins of the scour zone are considered to be ice margins. This interpretation is further supported by the recognition of thicker accumulations of sediment interpreted as till at zone boundaries.

The arcuate scours are attributed to large icebergs. Keels were up to 300 m across and, assuming a marine limit of 150 m above present at deglaciation (Craig, 1969), the iceberg draft must have reached 350 m resulting in a width-to-height ratio of approximately 1:1.4 (assuming the width of the plough mark equals the width of the berg). This indicates scour formation by large, tabular icebergs. In the modern glaciomarine environment, bergs of similar dimensions are produced from floating glaciers or ice shelves (Robe, 1980) through stresses produced either by periodic changes in water level through tidal or wind action or single event impulses such as storm surges, tsunamis or earthquakes (Holdsworth and Glynn, 1981; Holdsworth, 1978).

The dimensions of the icebergs forming the arcuate scour and the limited extent of the arcuate scoured zone suggests development in a confined bay (a calving bay (?)) during the initial breakup of the Late Wisconsin ice sheet when ice

thickness was at a maximum. The arcuate nature of the scours has been attributed to tidal driven currents moving icebergs within the calving bay (Josenhans et al, 1988). Alternatively, it is proposed that the scouring may result from a single catastrophic event associated with the sudden drainage of proglacial Lake Agassiz to sea-level (Henderson and Josenhans, 1987). The significant instabilities and turbulence produced during this event could lead to rapid disintegration of the glacier (or ice shelf) through accelerated iceberg production.

Isolated, wide, linear scours (>200 m wide) present in water depths exceeding 150 m in western and north-central Hudson Bay cut arcuate scour marks. They also indicate formation by large icebergs similar to those discussed above and are probably also associated with the initial stage of deglaciation of the bay.

Subparallel to parallel iceberg scours (Fig. 2.13c) are present in the northwestern quadrant of Hudson Bay. The cross-cutting relationships and sudden terminations observed in the features distinguished them from glacial flutings (Fig. 2.11a). Scour orientation tends to follow bathymetric contours and, although no direction is indicated by the features, it is assumed that ice flow was downslope toward the deeper water of Hudson Strait. Most parallel scour features average 50 m in width, and their distribution is generally restricted to shallower parts of the bay (<180 m). The close packing implied by the distribution of the scours and their consistent orientation suggest movement of an icepack en masse under a sustained force. Morphologically similar features have been described from the Beaufort Sea by Remnitz and Barnes (1974) in shallow water (up to 38 m) and interpreted as sea-ice plough marks formed by pressure ridges in seasonal ice. Waters in Hudson Bay where parallel scours occur are too deep for formation by modern sea-ice; however, it is possible that glacial ice packs, formed during deglaciation, produced the features.

Other areas of the seafloor are covered by narrow, subparallel to randomly oriented scours. These are the youngest scour features present in the bay. They tend to be restricted to bathymetric highs with the lower limit of scour varying from 170 m in Hudson Strait, to 150 m on Midbay Bank and 100 m near southern Winisk Trough. These scour limits imply a reduction in berg size from the original large, tabular icebergs forming the arcuate scour. Changes in scour morphology from the broad flat-bottomed arcuate and parallel scours to narrow flat-bottomed or v-shaped scours also reflect changes in berg geometry. The predominantly random pattern of these bergs suggests free, unrestricted movement in response to wind and/or tidal currents. It may be postulated that these icebergs formed later in deglaciation when the ice sheet was thinner and perhaps highly crevassed due to increased glacier flow in response to rapidly changing ice profiles. Variations in the limit of random scour throughout the bay may relate to differences in berg size, the nature of deglaciation and/or the relative rate of isostatic uplift.

Some areas of Mansel and Midbay Bank remain essentially unscoured even though depths are well within the limit of iceberg scour. The lack of scour and mottled, irregular nature of the seafloor in these areas suggests that a late, protective ice cover may have remained during the scouring phase of deglaciation as discussed earlier. Unscoured areas within bathymetric lows may also indicate the presence of a late ice cover or, more likely, the lack of scour because these areas lie below the limit of iceberg scour.

The distribution of moraines and ridges is shown in Fig. 2.16. Two large asymmetric moraines are present off the Keewatin coast (Fig. 2.8) and may represent a stationary front of the Keewatin ice sheet. Major moraines have also been interpreted in the northern part of the bay, northeast of Coats Island, and between Mansel Island and the Ungava Peninsula

(Josenhans et al, 1988, pg.276). The sedimentary sequence west and north of these features thickens significantly toward Hudson Strait. Although these sediments may have preferentially accumulated in the bathymetric lows of Hudson Strait, the thick sequences in association with the moraines implies that an ice margin position may have remained stationary in that area for some time.

2.4. Core Descriptions

Core data obtained from published descriptions (Leslie, 1965) and shipboard observations (Hudson 86-040 and 87-028) at widely separated sites within the bay are summarized in Appendix B. Leslie (1965) examined the distribution of microfauna within six cores and established criteria for paleoecological interpretations using foraminiferal associations, diversity and abundance. In general, however, genetic interpretations of the stratigraphy are based solely on detailed sedimentological descriptions. Results from the analysis of both sediment composition and microfauna are not yet available from the more recent cores (Henderson, in press; de Vernal et al, in press). Cores collected in 1971 (Lewis and Sanford, 1971) have been examined for texture and composition, although desiccation has obliterated sedimentary structures.

Based on available descriptions, sedimentary facies were characterized using the lithofacies code of Eyles et al (1983) (Appendix B). These facies are interpreted as representative of four main depositional environments defined as follows:

Post-glacial, open marine environment: fine-grained clastic sediment transported into the bay by rivers or reworked from shallow nearshore deposits by marine currents and deposited offshore;

Glaciomarine/Glaciolacustrine environment: Generally fine-grained, ice-proximal sediment deposited in a lacustrine or marine environment with the sediment supply and mechanisms

of transport to proximal basins strongly controlled by the debris entrained within the glacier;

Glacial environment: Unsorted sediment deposited directly or indirectly by the glacier, either subglacially or at the ice margin; sediment composition is a direct reflection of the material entrained by the glacier;

Fluvial/Glaciofluvial Environment: Sorted sands and gravels either deposited by modern or older fluvial systems or, by glaciofluvial processes where the sediment source is related to material entrained within the glacier although the depositional site may be subglacial or subaqueous.

The stratigraphy in the bay is variable and reflects the complexity of sedimentation in response to glaciation and the influence of the marine environment. From core descriptions and interpretations (Appendix B), the following conclusions regarding sediment characteristics are presented:

- 1) The upper unit in most cores consists of an olive grey, foraminiferal, silty clay of variable thickness attributed to post-glacial deposition. The low pebble and sand content of this unit suggests that sea-ice rafting is minor.
- 2) Cores in central Hudson Bay exhibit reddish brown surficial material. Leslie (1964, 1965) reports that the areal extent of this unit corresponds to bathymetric low areas of the bay and attributes formation to oxidation of fine particles during suspension settling through the water column. He limits the occurrence of the red-brown colour to the top few centimetres (<8 cm) of sediment, but observations from core HU 87-028-035 indicate the colour persists and includes several different facies. This suggests that the colour may be related more to sediment provenance. The composition of reddish brown tills (7.5YR, 10YR) in the Hudson Bay Lowlands, deposited by ice flowing south, has been linked to sources in central Hudson Bay (Wyatt, 1987; Thorleifson, 1989).

- 3) The character and thickness of the glaciomarine deposits differs throughout the bay. Grain size varies but is commonly fine-grained with higher proportions of sand and silt than post-glacial sediments described above. The unit tends to be laminated, the lamination being defined by variations in colour, composition and/or grain-size. Isolated pebbles or lenses and/or interbeds of sand, granules or diamicton may be present. In the coarser grained units, laminations and/or interbeds are commonly graded.

Deposits in Evans Strait (>5 m) are thick compared to those in central Hudson Bay (0.5-3.0 m). No glaciomarine sediment was recognized in southwestern and eastern Hudson Bay, although short cores in these areas make the results inconclusive. Lack of significant accumulations of glaciomarine sediment in the bay suggests rapid deglaciation.

- 4) Cores commonly bottom out in a compact silty or sandy diamicton, interpreted as a basal till. Thick diamicton sequences and units have been recovered in the bay, however, and vary from massive (HU 87-028-015), to stratified and/or graded (HU 87-028-001 and 004). In the latter case, at least, the diamicton facies may represent ice marginal glaciomarine deposition.
- 5) Sorted sand and gravel units in cores HU 87-028-090, 61HB-231, and HU 87-028-041 (Appendix B) suggest strong current activity. No current indicators have been recognized due, primarily, to disruption during coring.

Leslie (1965) relates the well sorted sand offshore from the Churchill River to post-glacial fluvial sedimentation on the basis of the microfauna. This depositional processes is not applicable to all sorted deposits within the bay, however. Sand underlying marine sediment offshore from the Nelson/Hayes River (Core HU-87-028-090) estuary occurs in large sand waves cut by iceberg scours as observed on sonographs from the area (Fig. 2.14). This suggests formation

prior to deglaciation, when sea-level was significantly higher than present.

Deposits of sorted sand and gravel in the Winisk Trough (Core HU 87-028-041) are also overlain by fine-grained post-glacial(?) sediment. These sediments are not scoured; however, the units are tentatively interpreted as subglacial or subaqueous ice-marginal glaciofluvial deposits based on their location in central Hudson Bay.

2.5. Discussion

The results of the geophysical and geological survey in Hudson Bay indicate that the sediment is largely glacial (Fig. 2.4) (Appendix B). The interpretation of the acoustic facies is supported by observations from cores collected along seismic lines. However, direct comparison between acoustic and sedimentary facies of the surficial deposits is constrained by several factors.

The first is imposed by the limited geophysical coverage in the bay and the acoustic equipment used. A veneer of fine sediment is difficult to discern on subbottom profiles and can be penetrated by the acoustic signal from the sidescan system. Therefore, a post-glacial sediment cover up to a meter thick cannot be evaluated from the acoustic records.

A second factor is related to the widespread distribution of seafloor features attributed to deglaciation and the extent of sediment reworking by iceberg scour. Intensive scour in areas of parallel reflectors suggests nearly complete obliteration of the original stratification and development of a massive, unstratified acoustic signature (Fig. 2.7). How much this reworking has modified the texture and composition of the glacial sediment is unknown.

Thirdly, because the seismic record only represents the acoustic response to sediment characteristics, seismic facies analysis is limited as a tool for the interpretation of de-

positional processes. This is particularly true when attempting to assess the degree of sediment modification of a particular facies by such activities as marine currents, resedimentation, and/or sea-ice rafting of debris.

With few exceptions, core stratigraphy indicates a general continuum in sediment texture from coarse-grained glacial and glaciomarine diamictos to fine-grained post-glacial muds with minor dropstones. The major factor in differentiating between depositional environments as indicated by the cores is the relative proportion of coarse-grained material. It is the regional distribution and compositional trends of this coarse sediment, entrained within the glacier and deposited either subglacially or at the ice margin, which will aid in the resolution of Late Wisconsin ice sheet dynamics.

CHAPTER 3

TEXTURAL CHARACTERISTICS OF SURFICIAL SEDIMENTS

3.1. INTRODUCTION

Textural analysis has been widely used to identify facies and the environmental factors affecting sediment transport and deposition in glaciated marine basins (Winterhalter, 1972; Barnes and Reimnitz, 1974; Kravitz, 1976, 1982, 1983; Bjorlykke et al, 1978; Anderson et al, 1980b, 1984; Domack, 1982; Clark and Hanson, 1983; Elverhoi, 1984; Rise and Rokoengen, 1984 among others). Criteria used to distinguish glacial from other types of sediment are primarily related to the lack of sediment sorting by ice.

The most effective method for facies differentiation is based on analysis of grain size distribution and the relationship between grain size statistics. In this chapter, the regional distribution of gravel, sand, silt and clay are examined and, where possible, more specific grain size parameters, particularly sorting, are used to define the characteristics of specific sediment types. The distribution of the coarser size fractions (sand and gravel) in the seafloor sediments is of particular interest since few sedimentary processes, other than those associated with glaciation or sea-ice rafting, can transport this material to central Hudson Bay. A major problem is differentiating between sediment deposited by Quaternary and post-glacial marine processes, and assessing the relative contribution by sea-ice versus iceberg rafting.

3.2 DATA EVALUATION

Data sources, as well as sampling and analytical procedures, are outlined in Table 3. In all cases, the sample represents the upper portion of sediment with a maximum penetration of approximately 20 cm depending on the shape and design of

TABLE 3

SAMPLING AND ANALYTICAL PROCEDURES, GRAIN-SIZE DATA

Year	Grab Sampler	Analytical Laboratory	Analytical Technique (Grain Size)	Reference
1961	Dietz-Lafond	University of Southern California	>2mm fraction, removed and studied separately <2mm >0.062mm, Emery settling tube (Emery, 1938) <0.062mm pipette method (Krumbein and Pettijohn, 1938)	Leslie, 1963 Pelletier, 1968, 1969
1965	Van Veen	B.I.O. Dartmouth, N.S.	total sample analysed by conventional sieve and pipette methods (Krumbein and Pettijohn, 1938)	Pelletier, 1968, 1969, 1986.
1971	Shipek	T.S./G.S.C. Ottawa, Ont.	>2mm fraction, sieved and studied separately <2mm fraction, conventional sieve and pipette methods (Folk, 1968; McDonald and Kelly, 1968)	-
1984	Van Veen	Oceanchem Ltd. Dartmouth, N.S.	conventional sieve and pipette methods (Folk, 1968)	Well site Surveys, Geomarine Associates Ltd., Hfx. 1985
1986	Van Veen	T.S./G.S.C. Ottawa, Ont.	>2mm fraction, sieved and studied separately <2mm fraction, conventional sieve and pipette methods (Folk, 1968; McDonald and Kelly, 1968)	-

the sampling equipment (for technical description see Bouma, 1969; p. 313)

Analysis of regional textural variations in Hudson Bay are based on percentages of gravel, sand, silt and clay calculated, for the most part, from complete grain size analyses (Appendix C). The gravel fraction (>2 mm) was determined as a percentage of total sample weight to minimize the effect of a single large cobble on grain size parameters. Gravel values were not available for 1961 samples. Sand (<2 mm to >0.063 mm), silt (<0.063 mm to >0.004 mm), and clay (<0.004 mm) ratios represent percentages by weight of the total sample exclusive of the gravel fraction. The results in Appendix C preferentially list areas where penetrable sediment covers the seafloor.

Among data sets, the analytical techniques are similar with the exception of the use of the Emery settling tube for sand determinations in 1961 samples. Schlee et al (1965) evaluated sieve and settling tube techniques and concluded that results were comparable and adequate for determination of grain size parameters. Consequently, variations in results due to differences in laboratory technique appear minimal.

Within the 1965 sample set, significant discrepancies are present in results from some, but not all, duplicate analyses (eg. 65HU 0093, 65TH 0286, 0389, 0408). Sand values vary up to 40% and differences in clay/silt percentages reach 20%. The problem is difficult to assess since no consistent error is recognized. All samples were processed in the same laboratory, presumably using a standard technique (Table 3). Discounting basic laboratory error, two possibilities exist for the variation in results. Firstly, the ratios may reflect textural heterogeneity within the original sample, eg. lenses or laminations of varying grain size. Secondly, problems in silt/clay values may be related to the flocculation of marine clays (Gibbs and Konwar, 1982) and the use of dispersing agents in the analyses to break up aggregates. It is possible that complete

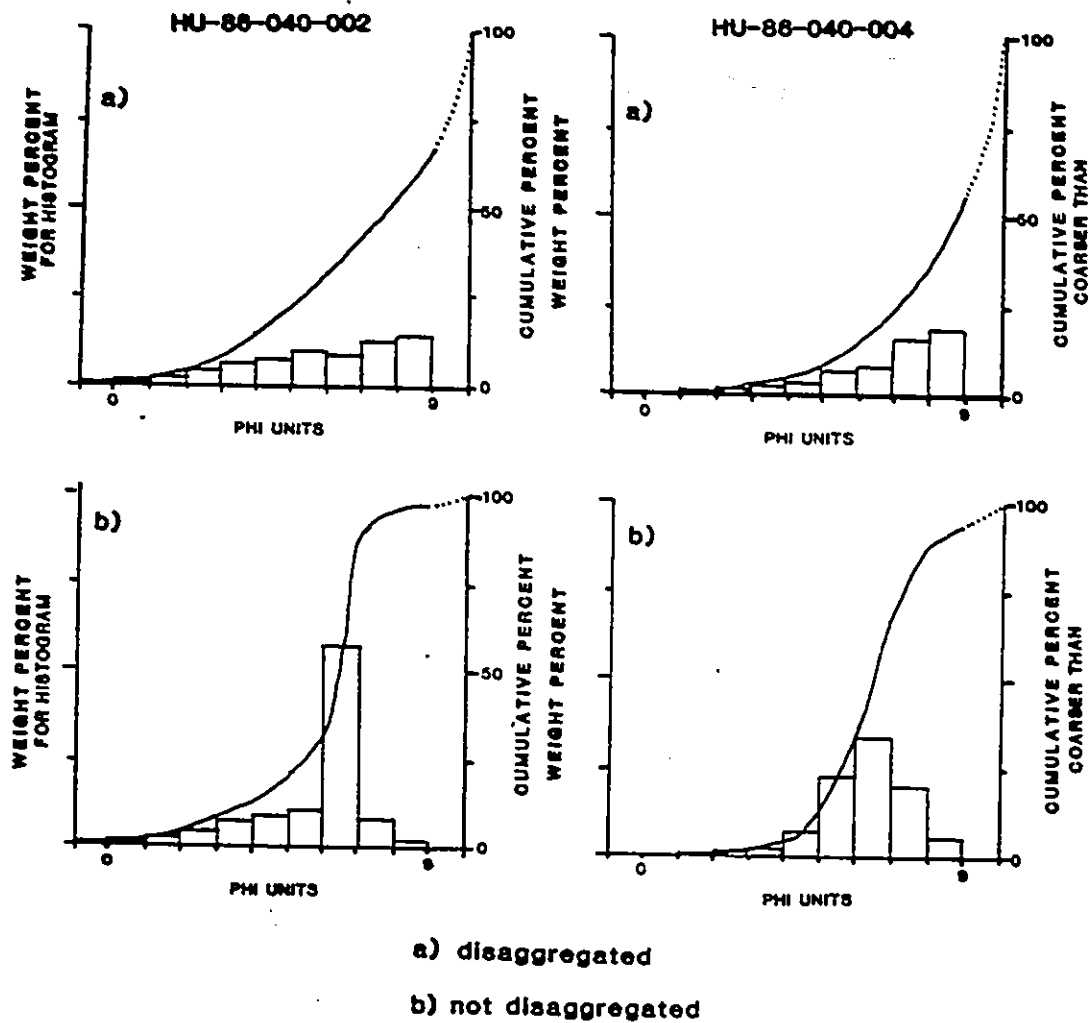


Figure 3.1: Effects of disaggregation on grain-size distribution. The upper cumulative frequency curve represents grain-size distribution of sample treated with a 0.5N solution of sodium hexametaphosphate.

dispersion was not always achieved. Results of the analyses of two 1986 samples with and without a disaggregant (sodium hexametaphosphate) are shown in Fig. 3.1. Significant differences exist in proportions of silt and clay.

Direct evaluation of the significance of either textural or analytical factors on the grain size ratios of the 1965 samples is impossible. Where duplicate analyses are present, they are included in the data base.

Because of the inconsistencies in the 1965 analyses and the incomplete data from 1961 samples, detailed examination of grain size distributions and related statistical parameters is limited to the 1971 sample set. The analytical techniques for these samples were outlined in McDonald and Kelly (1968). In addition, observations made during sample collection are available (Zevenhuisen, 1986).

3.3. REGIONAL TEXTURAL VARIATIONS

The geographic distribution of the various grain-size intervals was contoured using the Appmap programs (Ellwood, 1981) (Appendix D). The results are shown in Figs. 3.2 - 3.5.

3.3.1. Gravel Distribution

The percentage gravel in the surficial sediment of Hudson Bay varies from zero to 98% by weight. This statistic may be somewhat misleading, but is plotted because the presence of a gravel fraction, particularly in the central parts of the bay, is a significant indicator of glacial or possibly, sea ice rafted sediment.

Concentrations of gravel exceeding 25% of total sample weight occur in the following areas (Fig. 3.2):

- (1) Flanks and crests of bathymetric highs within the central part of Hudson Bay. These include Midbay and Mansel Banks and the Ottawa Ridge.

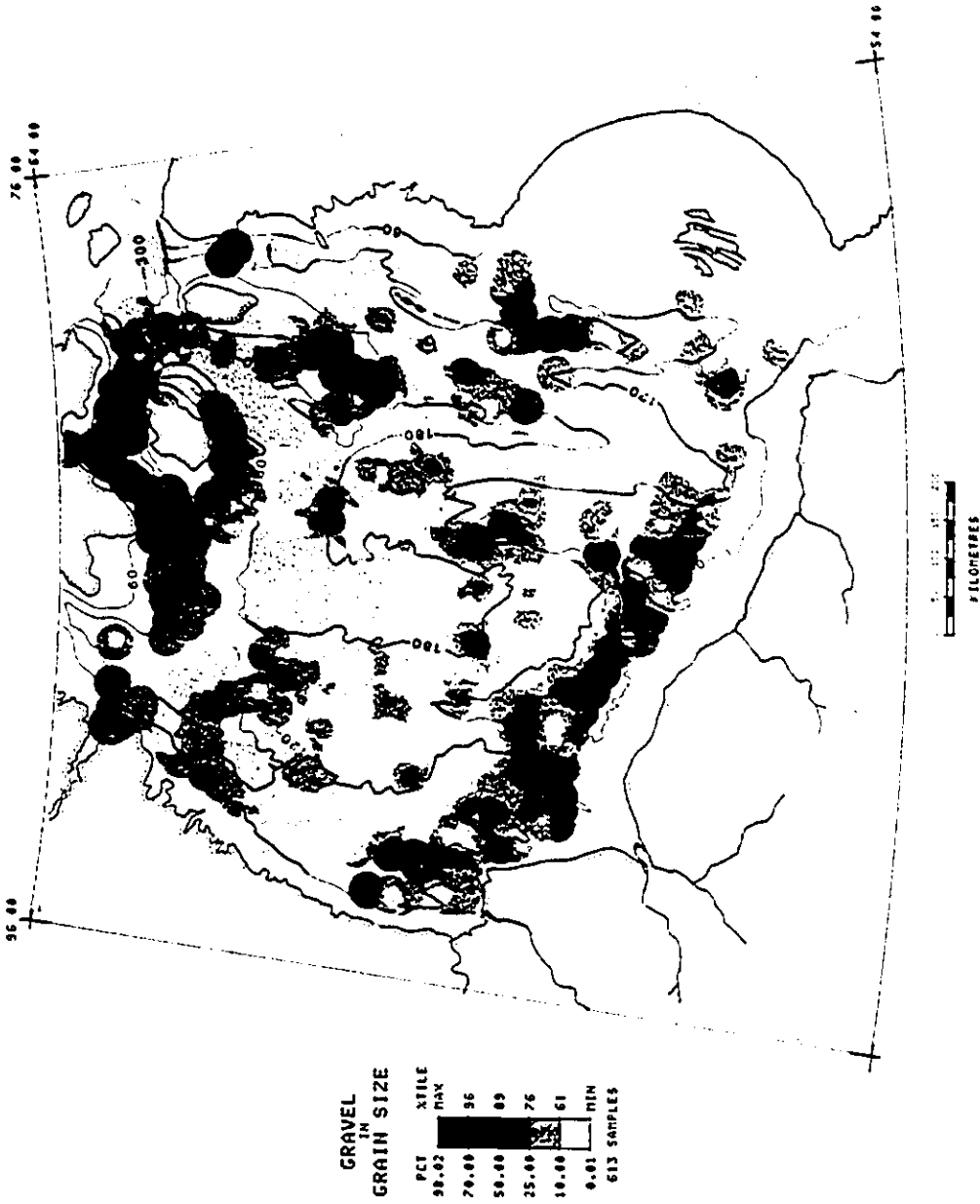


Figure 3.2: Appmap plot showing gravel (>2mm) content of surficial sediment. Bathymetric contours are in metres. (PCT, weight percent gravel of total sample; %tile, percentile value)

- (2) The northeastern entrance to the bay, particularly between Mansel Island and the Ungava coast and Fisher and Evans Straits including the southern coastal areas of Southampton and Coats Islands. Elevated gravel percentages are also present in the central channel between Coats and Mansel Islands.
- (3) Coastal areas, particularly in southern and southwestern Hudson Bay extending almost continuously from the Winisk River in the east to the Keewatin coast. High gravel percentages extend offshore for 150 to 200 km.

A significant proportion of gravel is also present in the sediment of northwestern Hudson Bay. Lowest values occur in Hudson Basin, the channel between Coats and Mansel Islands, and the Winisk Trough.

3.3.2. Sand Distribution

Sand values vary from 0.1 to 95% with a median of 14%. The distribution is similar to gravel (Fig.3.3). Highest values (>50%) occur (1) on bathymetric highs in the central part of the bay, (2) at the northeastern entrance to the bay including Fisher and Evans Straits and the coastal areas of Coats and Southampton Islands, and (3) along the western and southwestern coasts. Extremely sandy sediment at the mouth of the Churchill and adjacent rivers, forms a narrow band trending eastward from the river mouth. This material may represent a fluvial deposit with the eastward trend related to the counterclockwise current regime in the bay (Prinsenber, 1986). Sandy sediment also extends southward from Chesterfield Inlet, also possibly under the influence of this current regime. Similar well defined coarse sediment concentrations are not present offshore from the Nelson/Hayes, Severn or Winisk River systems, most likely due to the lack of nearshore data. In southern and southwestern Hudson Bay, sandy sediment is present as a continuous blanket extending as far east as the Winisk Trough and 50-200 km off-

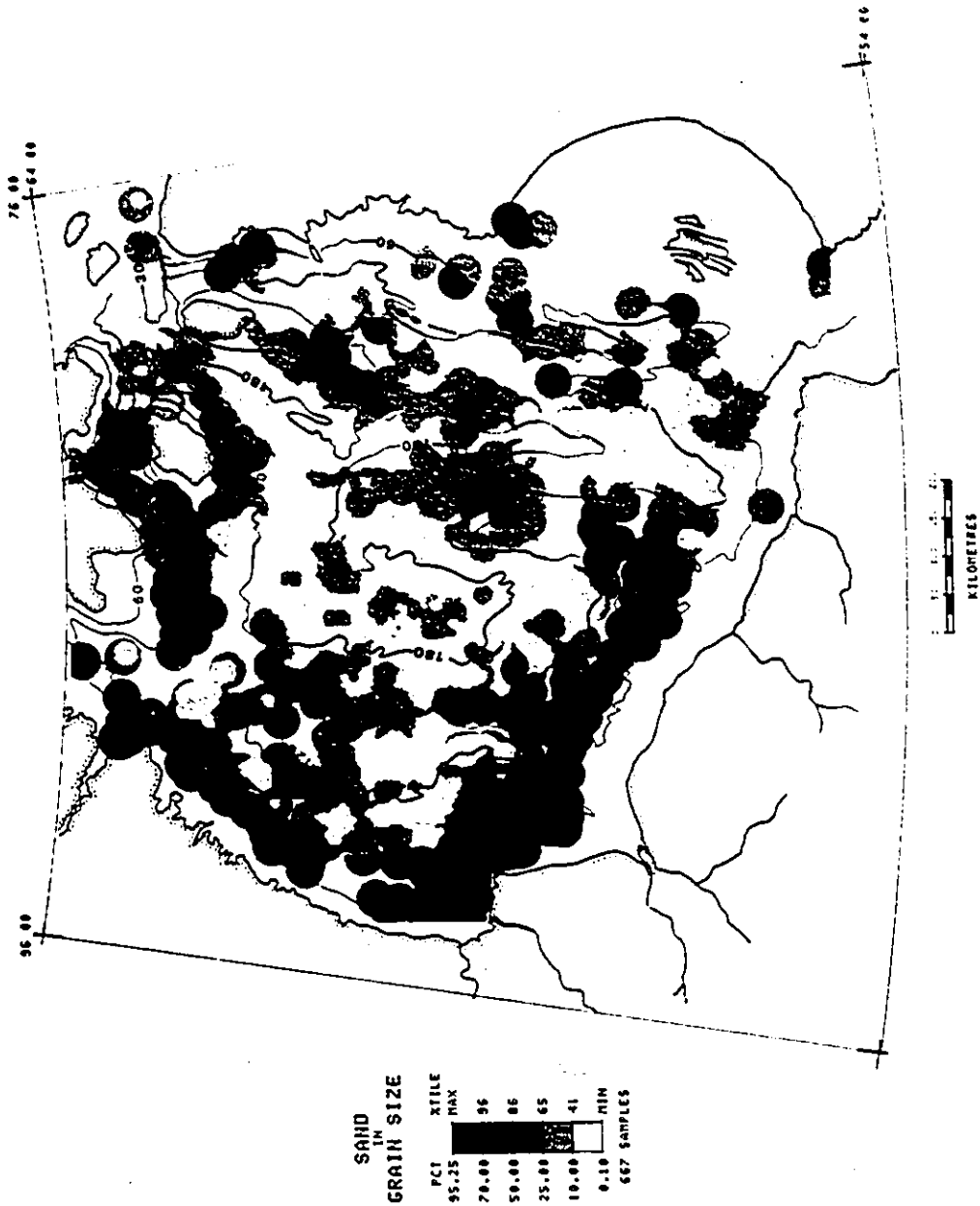


Figure 3.3: Appmap plot showing in sand (0.063 - 2mm) content of surficial sediment. Bathymetric contours in meters. (PCT, weight percent sand of sample, excluding gravel; %tile, percentile value)

shore. Highest sand percentages are associated with sediment overlying bathymetric highs.

As with gravel distribution, low sand percentages (<10%), are restricted to sediment in basinal areas including parts of Hudson Basin, the central channel between Coats and Mansel Islands and the southern Winisk Trough. Isolated areas of low sand percentages are also present in surficial deposits offshore from the Belcher Islands, the Ungava coast north of Richmond Gulf and the Keewatin coast.

3.3.3. Silt/Clay Distribution

The distribution of silt and clay is shown in Figures 3.4 and 3.5 respectively. These fractions are the most significant components in a large number of the samples. The proportion of both silt and clay in the sediment increases offshore. In general, sediment in western and northern Hudson Bay has a higher silt content than that of the east (Fig.3.4). High values (<50%) are restricted to deposits in depressions offshore from the Manitoba and Keewatin (Roes Welcome Channel) coasts, the channel between Coats and Mansel Islands, and southern Winisk Trough, as well as basinal areas adjacent to Mansel and Midbay Bank.

Clay percentages (>50%) (Fig. 3.5) are high in samples collected from bathymetric lows in central and eastern Hudson Bay, particularly parts of the Hudson Basin and Winisk Trough, and areas west of Mansel Bank, the Belcher and Ottawa Islands and Ungava coast.

3.4. CHARACTERISTICS OF GRAIN SIZE DISTRIBUTION

Textural criteria used to distinguish glacial from other deposits are based on the inefficiency of sediment sorting by ice. However, sorting alone is inadequate to fully describe grain size distributions. A more effective discriminant is the relationship between statistical parameters such as mean grain size and sorting (Griffiths, 1967; p. 308).

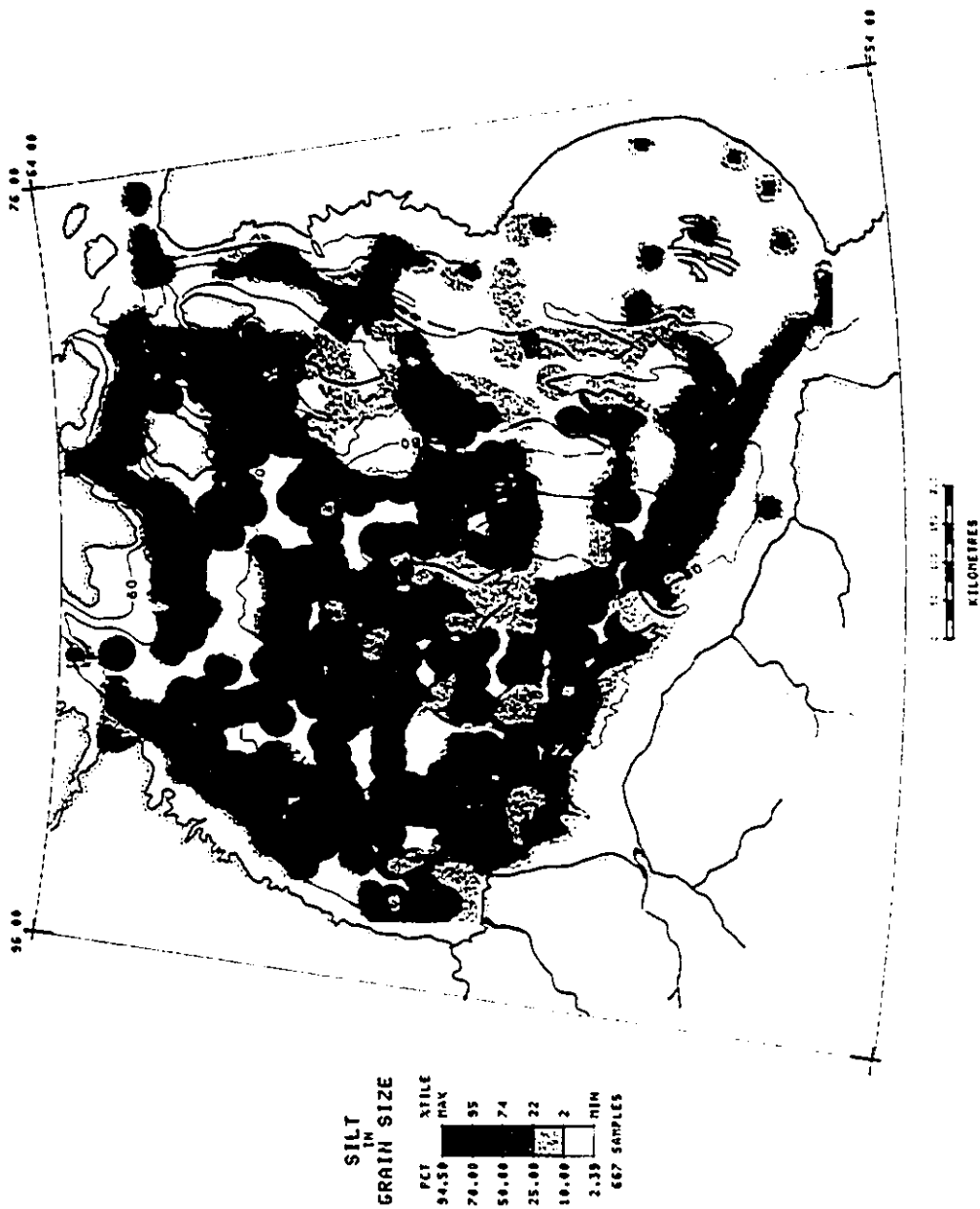


Figure 3.4: Appmap plot showing silt (0.004 -0.063mm) content of surficial sediment. Bathymetric contours in meters. (PCT, weight percent silt of sample, excluding gravel; %tile, percentile value)

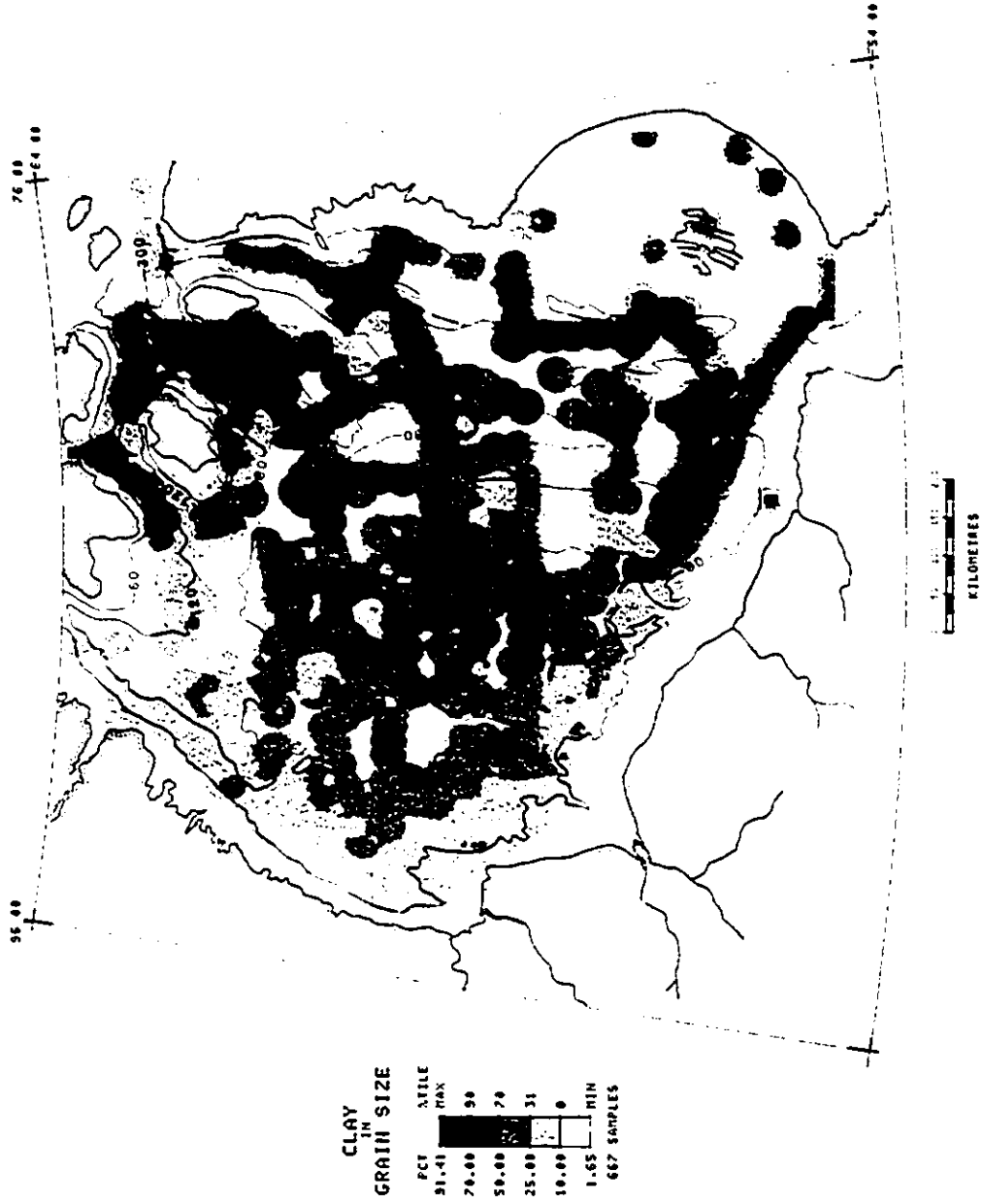


Figure 3.5: Appmap plot showing clay (<0.004mm) content of surficial sediment. Bathymetric contours in meters. (PCT, weight percent clay of sample, excluding gravel; &tile, percentile value)

Using 1971 data (Appendix C) the sorting coefficient (Inman, 1952) was plotted against mean grain size (Inman, 1952) to define sediment types within the bay (Fig. 3.6). Exclusion of the gravel fraction from the analyses defines the upper limit of the cumulative frequency curve at 2 mm. The lower limit is 0.002 mm and all finer material is included in the lowest class interval of the grain size distribution. In approximately 20 samples, the percentile value required for calculation of the grain size statistics fell in a limiting class. No extrapolation was made and, in these cases, the statistics could not be calculated.

3.4.1. Definition of Sediment Types

Using the 1971 data, the plot of sorting coefficient versus mean grain size reveals three main groups together with their mixed products (Fig. 3.6).

Group 1: Sorted Sand: sand to coarse silt, moderate sorting

These sediments are moderately to well sorted with mean grain size in the sand to coarse silt range. Clay percentages (<0.002mm) are low, commonly less than 10%, and gravel values are highly variable ranging from zero to 50%. With few exceptions, all samples are found at depths less than 100 m.

The generally good sorting of sediment in this size range implies some current activity. This control may occur during initial deposition, possibly from the traction load of a fluvial or glaciofluvial system (Allen, 1979; Gilbert, 1983), and/or following deposition, through the reworking of a coarse grained, possibly unsorted, sediment. Sediment modification is particularly active in the shallow marine environment under the influence of ocean, wind, and/or tidally induced currents (Swift et al, 1971).

Group 2: Diamicton: sandy to silty, unsorted to poorly sorted

The diamictons are unsorted to poorly sorted, with mean grain size ranging from very fine sand to coarse silt. Gravel percen-

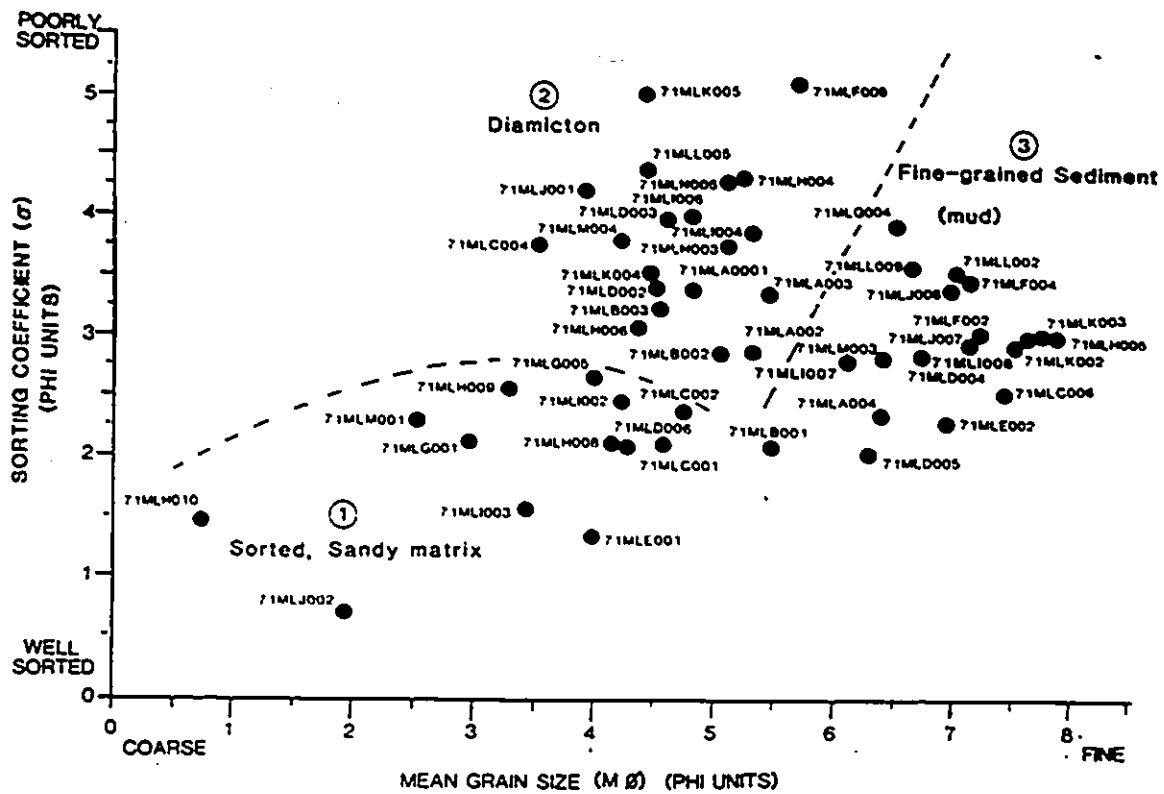


Figure 3.6: Plot of sorting coefficient versus mean grain size for 1971 samples. The samples are divided arbitrarily into three broad groupings as indicated.

tages vary from 12 to 60% and clay values are moderate (15-30%). These sediments occur in water depths ranging from 60 to 130 m.

The wide distribution of material in all size classes indicates the general lack of sorting by the transporting medium. Diamictons are commonly derived from erosion by ice and represent material deposited directly from a glacier, either subglacially or at the ice margin, or material rafted by sea ice (Barnes and Reimnitz, 1974) or icebergs (Anderson et al, 1980b; Clark and Hanson, 1983). Texturally similar unsorted sediments are also deposited from sediment gravity flows although these are typically thinner and less extensive than glacial deposits (Anderson et al, 1983).

In core descriptions (Appendix B), similar diamicton facies have been interpreted as glacial deposits.

Group 3: Fine-grained sediment (Mud): variable coarse component

Samples of this group are characterized by a range in sorting which varies from fair to poor, a negative skewness with clay percentages exceeding 25%, and low gravel values (0-8%). Samples may be bimodal in the silt and clay or fine sand and silt mode. The mean grain size ranges from medium to fine silt. The sediment type is widespread throughout the bay occurring at depths between 85 and 200 m.

Similar sediment in Hudson Bay cores (Appendix B) is attributed to either glaciomarine or post-glacial sedimentation depending on sedimentary structures and stratigraphic position. In general, the gravel fraction is lower in post-glacial sediment of central Hudson Bay than in glaciomarine sediment.

The texture of Group 3 sediments is attributed to the interaction of sediment deposition offshore under the influence of a marine or glaciomarine current regime and sediment rafted by icebergs, sea ice or both (Anderson et al, 1980a, 1983; Clark and Hanson, 1983). The variation in sorting is imposed by the current strength and the degree of winnowing of rafted sediment falling through the water column (Drewry, 1986).

Very fine-grained sediment with high clay percentages (45-70%), although not plotted in Fig. 3.6, are also included in Group 3. These samples generally lack a gravel component and are deposited in depressions at depths of 105-180 m. The fine grain size and general lack of a coarse component is suggestive of post-glacial sedimentation in areas of low current activity (Allen, 1979).

Extrapolation of the three sediment groups, defined using the 1971 data set, to the entire bay using all the available textural data requires the consideration of limiting factors. Sand:silt:clay ratios of 1971 samples plotted in Figure 3.7 show that most of Group 1 and 2 have greater than 25% sand, and the majority of Group 1 samples have less than 15% clay. Finer-grained sediments (Group 3) have less than 25% sand and could be distinguished by the relative proportions of silt and clay. It is felt, however, that sand and gravel content is a more effective parameter for distinguishing between glacial and post-glacial deposits, based on observations from the cores. The major division between sediment types, therefore, has been determined by the sand content. Fine-grained sediments with a significant gravel fraction (exceeding 1%) generally contain more than 10% sand. Consequently, sediment types within Hudson Bay are defined as follows:

- Type 1 (sorted, sand): >25% sand, <15% clay
- Type 2 (diamicton): >25% sand, >15% clay
- Type 3 (sandy mud): <25% sand, >10% sand
- Type 4 (mud): <10% sand

These types serve as a broad textural classification, based on grain size and sorting, that can be used to describe all seafloor sediments, indicate the regional distribution of sediment types, and provide a framework for the discussion of sediment composition. The extent of possible glacial or ice rafted sediment is reflected in the distribution of the coarser grained sediment (Types 1-3). However, textural criteria are

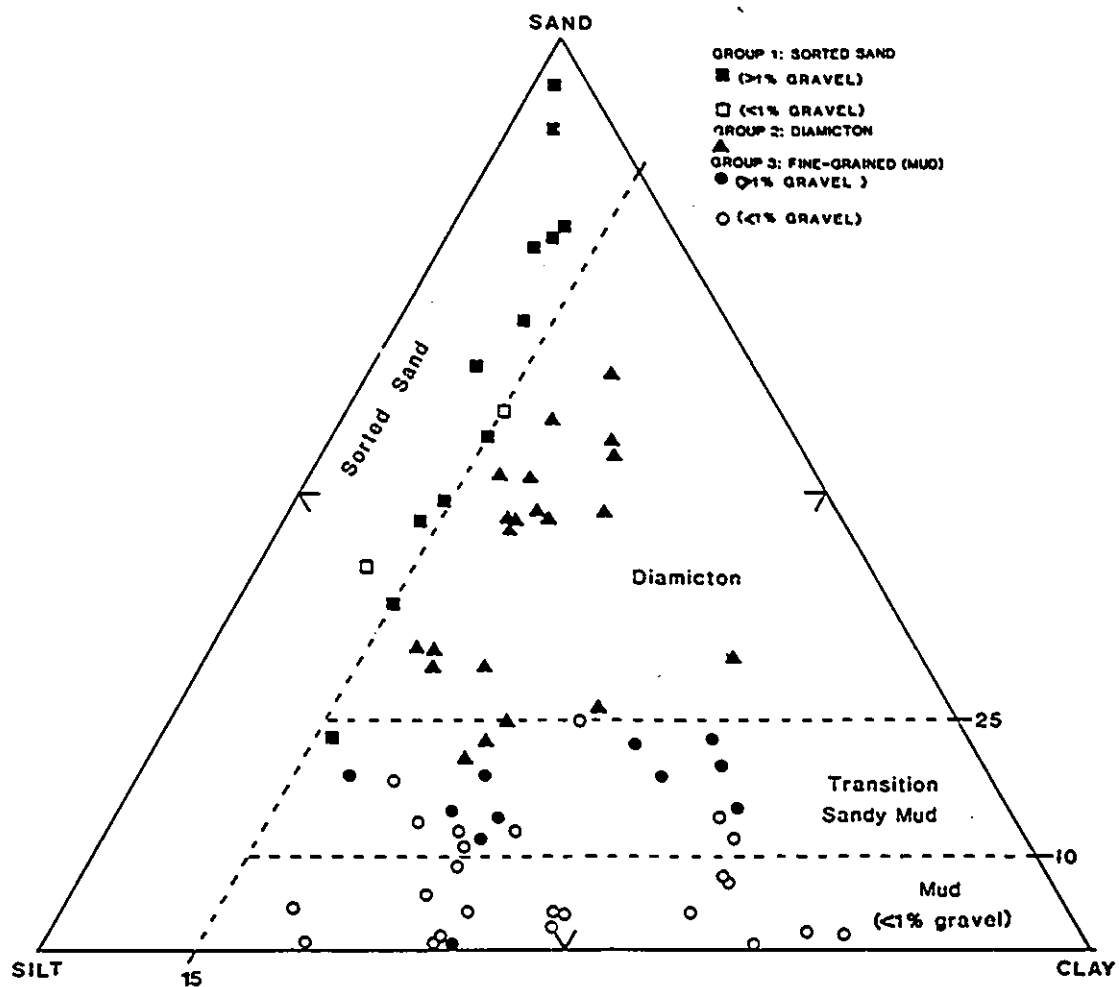


Figure 3.7: Ternary plot of matrix composition (i.e. gravel excluded) for 1971 samples. Results indicate the four sediment types defined on the basis of sand:silt:clay ratios.

unable to differentiate between iceberg and sea-ice rafted sediment.

3.4.2. Distribution of Sediment Types

The regional distribution of sediment types, based primarily on sand content of surficial sediments, is shown in Fig. 3.8. As recognized by earlier workers, a general relationship is present between bathymetry and texture, with the coarsest material occurring in coastal areas and on major bathymetric highs (Leslie, 1964; Pelletier, 1969, 1986). On closer examination, however, these broad trends are poorly defined, particularly toward the centre of the basin. Although sorted sands (Type 1) and diamictons (Type 2) are concentrated offshore and on bathymetric highs at relatively shallow to intermediate depths, they are also present in the deeper water of Hudson Basin and Winisk Trough. Similarly, sandy muds (Type 3) are widely distributed in offshore areas at intermediate depths and in coastal areas of southeastern Hudson Bay, north of the Winisk River, as well as Hudson Basin and Winisk Trough. Mud (Type 4) predominate in localized basins offshore from the western, southwestern and eastern coasts of the bay, and the deeper regional basins, particularly Hudson Basin and the southern Winisk Trough.

The textural variation and general absence of well developed trends (Fig. 3.8) indicates the complexity of sedimentation within Hudson Bay. This complexity cannot be explained solely through the simple hydrodynamic model suggested by Pelletier (1969, 1983). He concluded that textures of seafloor deposits reflect the energy regime in the bay, with most bottom sediment transported by rivers and dispersed throughout the bay by marine currents and sea-ice rafting (Pelletier, 1986; p.160). Conclusions from core and seismic analyses (Chapter 2), however, indicate that post-glacial sedimentation is limited and that a large part of the seafloor is covered by glacially derived deposits. The diversity and distribution of sediment types,

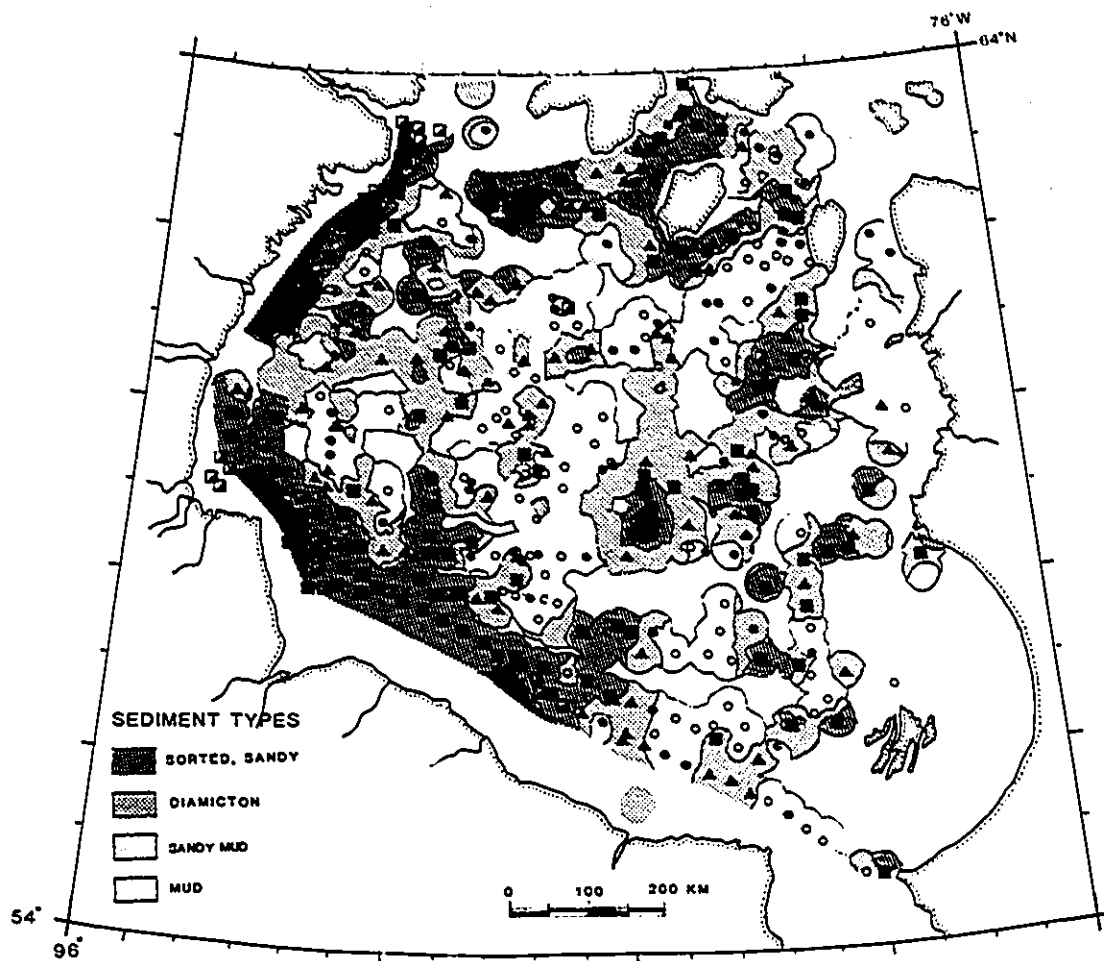


Figure 3.8: Distribution of sediment types in Hudson Bay. Symbols are as follows: x sorted sand with <1% gravel; ■ sorted sand with >1% gravel; ▨ diamicton; ▲ sandy mud; o mud with <1% gravel; ● mud with >1% gravel.

therefore, may be explained, at least in part, by the nature of the original glacial sediment. This implies that some of the "ice rafted" component defined by Leslie (1964) and Pelletier (1969, 1986) is of glacial origin.

3.5. SUMMARY

Four sediment types have been defined in Hudson Bay surficial deposits based on textural variation, particularly sorting and mean grain size. The classification and, therefore, the regional distribution of these sediment types is primarily dependent on the sand content of the deposits. Genetic interpretations of textures indicate that coarser grained sediments (Types 1-3) may be glacial or sea-ice rafted deposits. The wide distribution of these coarse-grained and poorly sorted sediments in central Hudson Bay suggests that processes other than post-glacial suspension settling and sea-ice rafting are responsible for sediment accumulation.

Models for sedimentation in glaciated marine basins and coastal areas of arctic and subarctic regions emphasize that surficial sediments are largely "relict" (Shepard, 1932; Emery, 1968), formed during Pleistocene glaciations and subsequently modified to varying degrees by post-glacial sedimentary processes (Swift et al, 1971; Winterhalter, 1972; Molnia, 1983; Elverhoi, 1984; among others). In Hudson Bay, the glacial history of the region as interpreted from onshore observations (Chapter 1) and acoustic facies analysis (Chapter 2) indicates that Quaternary deposits were drowned, without reworking, as marine water entered the region. The nature of the surficial deposits, therefore, depends primarily upon the character of the original glacial sediment, and, secondarily, on the degree of modification or burial by post-glacial sedimentary processes. Further understanding of these processes may be derived from the examination of mineralogic and lithologic components of the

sediment and the recognition of sediment transport paths through dispersal trends of distinctive rocks and mineral assemblages.

CHAPTER 4

COMPOSITION, PROVENANCE AND DISPERSAL TRENDS

4.1. INTRODUCTION

The composition of the surficial sediment was analyzed to determine the bedrock sources and to assess the nature of sediment transport. In Hudson Bay, the most basic source distinction is between Paleozoic carbonates, Proterozoic unmetamorphosed volcanic/sedimentary rocks and Precambrian igneous and high grade metamorphic rocks. Within these broad groupings, certain lithologies and mineral associations have been recognized in sediments exposed on adjacent land and within Hudson Bay that can be related to specific source areas (Shilts et al, 1979; Shilts, 1982; Henderson, 1983). The dispersal trends of these distinctive components provide a strong indication of the extent, nature and direction of sediment transport and deposition.

The degree to which sediment composition reflects the bedrock source from which it was eroded depends on the erosion process and the extent of sediment modification during transport, deposition, and possible diagenesis. In glaciated terranes, sediments, such as till, are composites of the bedrock traversed during glacier flow, whereas others, such as fluvial or marine sediments, are sorted aggregates derived from previously deposited till or till-like debris. Although these derived sediments have been subjected to post-glacial transport and chemical alteration, they still reflect their glacial source (Rencz and Shilts, 1980; p. 154). Therefore, to varying degrees, sediment composition reflects glacial transport (Shilts, 1976; Rencz and Shilts, 1980).

Through erosion and comminution, material is distributed within the sediments in different size fractions depending on the nature of the original bedrock source. The importance of

the relationship between sediment texture and composition has been outlined by many workers (Dreimanis and Vagners, 1971; Shilts, 1973; Kelling et al, 1975; Haldorsen, 1977; among others). For example, igneous and metamorphic rocks produce a matrix mode in the very fine to fine sand size range (Haldorsen, 1977) and carbonates in the silt sizes (Dreimanis and Vagners, 1971). In order to minimize these partitioning effects and determine the relative degree of sediment input from various sources, several size ranges must be examined.

Shilts (1973) defined four class sizes with significantly different compositional characteristics to adequately describe sediment composition. Gravel-size clasts (>2 mm) are composed mainly of rock fragments; the fine sand fraction (0.063 to 0.25 mm) is composed primarily of mineral grains which include quartz, calcite, feldspar as well as the bulk of the heavy mineral assemblage; the silt fraction (0.002 to 0.063 mm) is composed of quartz, calcite, feldspar and a minor proportion of the heavy minerals; and the clay size fraction (<0.002 mm) consists mainly of clay and other micaceous minerals as well as minor amounts of quartz, feldspar, calcite and aggregates of clay-size iron and other oxides. In the present study, compositional analysis was confined to three of the classes defined by Shilts (1973) primarily because of the nature of the archival material.

4.2. ANALYTICAL METHODS

The composition of the gravel, fine sand, and clay-size fractions were analyzed as indicated in Appendix A. Sample sites, although distributed throughout the bay, are limited by the original sampling grid, the available sample material, and the texture of the original sediment (Fig. 4.1). The relationship between sample type and compositional analysis is summarized below (as a percentage of the total number of analyses for each size fraction):

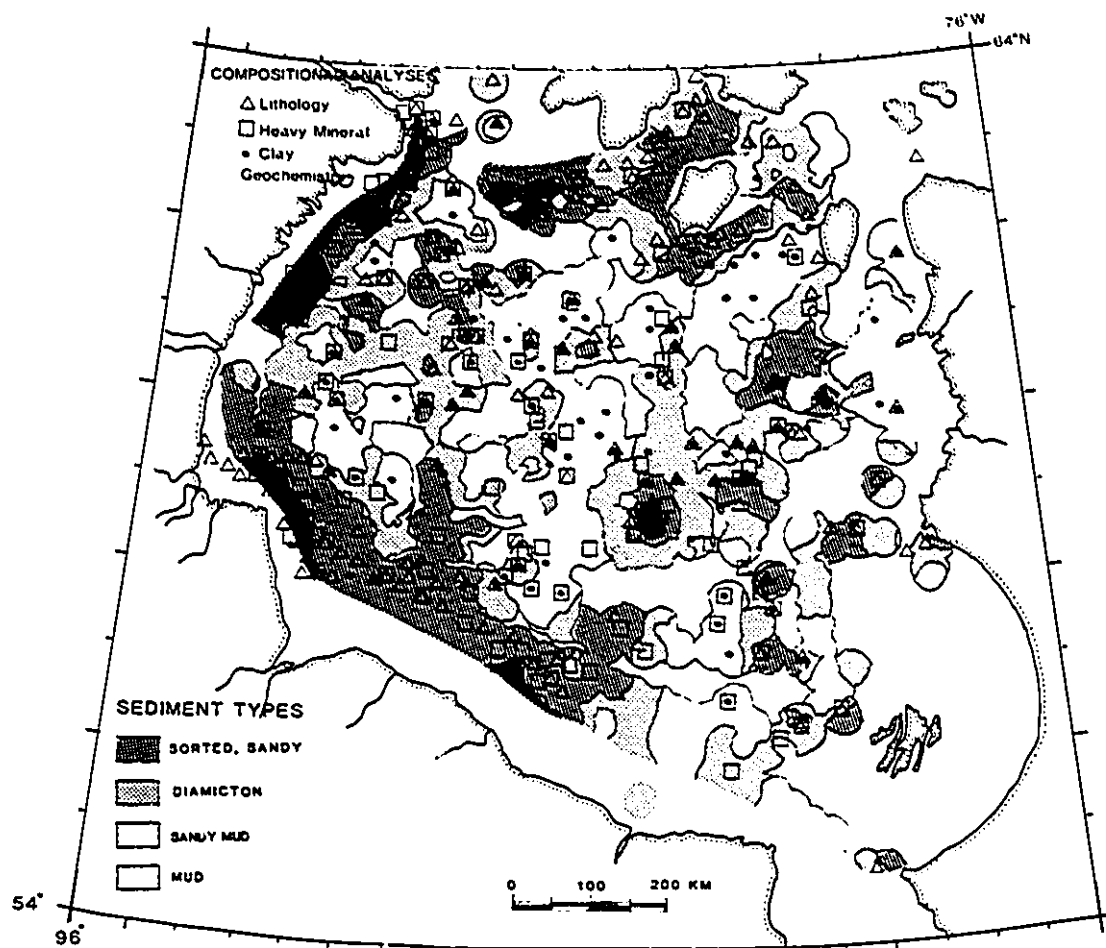


Figure 4.1: Site locations for compositional analyses in relationship to sediment type. (△, lithological analysis of gravel fraction; □ heavy mineral analysis; ● geochemical analysis of clay-size fraction)

	Type 1 and 2	Type 3	Type 4
	Sorted sand/Diamicton	Sandy mud	Mud
Gravel	66	25	9
Fine Sand	65	20	15
Clay size	23	26	51

Gravel and fine sand compositional analyses are associated primarily with the coarser sediment types while geochemical and mineralogical analysis of the clay-size fraction is more common in the fine-grained sediments. Complete analysis of the three specified size ranges is limited to twelve sites, although combined gravel and sand determinations are more prevalent (Appendix A).

4.2.1. Gravel Fraction

Sample material used in lithologic analyses was acquired from the residue of textural analyses or clay separations. The 2.0-5.6 mm fine gravel fraction was separated by dry sieving. The use of this fraction ensured consistent lithological identification and generally supplied sufficient material for a reliable count. The 2.0-5.6 mm fraction had previously been used for analyzing till samples from areas adjacent to and underlying Hudson Bay (Kaszycki and Shilts, 1980; Shilts et al, 1979; Shilts, 1982; Thorleifson, 1989). Consistent use of this fraction permits comparison of results (Henderson et al, 1987).

Only samples containing a sufficient proportion of the specific size fraction were used in the analyses. The lower weight limit was arbitrarily established at 2 grams, resulting in a minimum sample size of 50-100 grains depending on the lithological types. Domack (1982) indicated that 50 grains are significant for a representative count, although the error is relatively high (Van der Plas and Tobi, 1965).

Initial clast identifications were made visually and confirmed under the binocular microscope. When difficulties arose, thin sections were prepared for selected lithologies and examined under the petrographic microscope. Although many

lithologic variations were recognized, the clasts were ultimately divided into eight groupings consisting of either fairly broad divisions or more restricted distinctive lithologies that could be consistently and easily recognized. Percentages within each lithologic grouping were determined by weight of the total granule fraction and the results are summarized in Appendix E.

Since lithologic concentrations are calculated as percentages of total granule weight, values are intimately related to each other. Excessively high values of one variable depress values of the remainder. This dilution effect may influence the relative importance of specific lithologies within the sediment.

4.2.2. Fine Sand Fraction

The examination of the sand fraction was limited to the heavy mineral assemblage. Previous x-ray analyses of bulk sediment samples from Hudson Bay by Bayliss et al (1970) concentrated on the composition and distribution of the lighter minerals, specifically quartz, feldspar and calcite. These minerals lack a distinctive, closely defined, source area. In Hudson Bay, heavy minerals are a more sensitive indicator of provenance because they are derived almost exclusively from the Archean and Proterozoic rocks which outcrop adjacent to and partially underlie the area, and heavy mineral assemblages can be linked to specific rock types (Krumbein and Pettijohn, 1938; Pettijohn, 1957; Carver, 1971). Paleozoic carbonate rocks underlying the bay are not a significant source for heavy minerals, with the exception of siderite and possibly pyrite.

Methods of heavy mineral preparation and identification used in this study were outlined by Pare (1982). Selected samples were initially wet sieved to retain the 0.063-0.250 mm fraction, and subsequently dry sieved. Methylene iodide (s.g. 3.3) was used to separate heavy and light minerals by flotation, and magnetic minerals were removed using a hand magnet; all separates were weighed and respective percentages determined. The heavy minerals were mounted in Araldite 502 (n=1.56) on

microscope slides for petrographic study, using a representative split where sufficient material was available. Heavy minerals were identified and counted under a stereoscopic binocular microscope using reflected light. X-ray diffraction and/or petrographic examination was used for the identification of questionable mineral varieties prior to grain counting. During the count, a petrographic microscope was used to monitor optical properties of specific non-opaque minerals when difficulties arose. A description of the major mineral species is presented in Appendix F.

A total of 450 grains were counted from each slide using a "Swift" mechanical stage and automatic counter. Percentage frequency of each class was calculated based on the total number of grains counted, excluding amphiboles and clinopyroxenes. The specific gravity of these minerals brackets that of methylene iodide, so variations in their percentages may be an artifact. The results are summarized in Appendix F.

4.2.3. Fine-grained Fraction

Original material was fractionated for geochemical and mineralogical analysis. These analyses were attempted with some hesitation because of the extended storage time of the samples and ignorance of the storage history including previously applied procedures, if any. The clay-size fraction (<0.002 mm) was separated from bulk samples by centrifuge and decantation using a 0.5N solution of sodium hexametaphosphate for sediment dispersal (Higgins, 1982). It was then oven-dried, ground and analyzed for a suite of elements by Bondar-Clegg and Co. Ltd. using D.C. Plasma-Atomic Emission spectroscopy with hot HNO_3 -HCl acid dissolution. The results are summarized in Appendix G.

An overview of the mineralogical composition of the clay-size fraction was undertaken using selected samples in an E-W transect across the bay, and several sites offshore from the Nelson River. Suspensions were mounted on glass slides as oriented aggregates using the smear technique (Gibbs, 1965) and

analyzed by X-ray diffractometer with $\text{CuK}\alpha$ Ni-filtered radiation (2° $2\theta/\text{min}$; chart speed, 1000 cps). X-ray diffraction patterns were determined before and after glycolation (Carroll, 1970). Results are summarized in Appendix H, although no attempt was made to determine relative abundance.

Carbonate concentrations were determined on the silt plus clay fraction (<0.063 mm) of the sediment using the Leco carbon determinator. Bulk sediment samples were air-dried and sieved to <0.063 mm. Carbonate percentages are determined from the measurement of CO_2 produced by burning two sample portions of equal weight: one untreated, the other treated with dilute HCl. The fraction of inorganic carbon (non-carbonate) and calcium carbonate (or equivalent) in each sample is calculated and the results are tabulated in Appendix I. This method does not differentiate between biogenic and lithogenic carbonate.

4.3 Plotting Methods

Graphically illustrating variation in composition in Hudson Bay is difficult because of inequalities in sample density, small sample size and "random" fluctuations in specific values. Such problems lead to extensive extrapolation between observation sites and the opportunity for strong biases in data contouring. In order to minimize this possibility, both computer and hand contouring techniques were assessed.

(1) Appmap Programs

A discussion of the Appmap programs is given in Appendix D. Although these programs proved useful for contouring of textural data, they were not satisfactory for displaying the results of compositional analysis primarily because of the sparse sample distribution. The Appmap programs tended to display single spot values, or maps showing areas of high concentrations based on a single observation due to the overemphasis of anomalous values. Contouring was only effective in localized areas of high sample density.

(2) Trend Surface Analysis

Trend surface analysis was assessed using results of the heavy mineral determinations (Appendix J). This method tends to smooth the data and minimize the effects of local isolated concentrations (caused by such factors as hydraulic sorting, diagenesis and grain size variations) from broader dispersal patterns. Trends developed using this technique are similar to those resulting from Appmap programs but anomalous values, both high and low, are masked, leading to a smooth regular contoured surface.

(3) Hand Contouring

At the sampling scale of this study, the significance of anomalous values and contour irregularities cannot be reasonably assessed. Because the primary purpose of the compositional analyses is to establish sediment dispersal trends and to define regional facies on the basis of composition and texture, it is felt that the best representation of the observed data is by hand contouring. In general, contour intervals were chosen to indicate general trends in distributions, presence or absence of particular components, and/or the upper and lower values (tails) of the normal frequency distribution of the component. Hand contoured maps produced trends similar to those contoured by computer without masking site specific variations in values. These maps are used in the following discussions.

4.4. ANALYSIS OF THE GRAVEL FRACTION

The results of the lithological analysis are summarized in Appendix E. The distribution of five distinctive rock types in the gravel fraction (2-5.6 mm) of the surficial sediments is shown in Figs. 4.2-4.6. These types include igneous/metamorphic rocks (crystalline), grey/tan carbonates, red/pink carbonates, greywacke/argillites and Dubawnt Group rocks.

Paleozoic grey/tan carbonates and Precambrian igneous/metamorphic clasts have the widest distribution of any other

lithologic group, reflecting their extensive outcrop area (Fig. 1.5). Source areas for red/pink carbonate, greywacke/argillite, and Dubawnt lithologies are more restricted or more distant and this is mirrored by their lower percentages and more limited distribution throughout the bay.

4.4.1. Distribution and Dispersal Trends

Igneous/Metamorphic (Crystalline) Rocks

Igneous and high-grade metamorphic rocks outcrop in large areas of the Canadian Shield adjacent to, and partially underlying, Hudson Bay (Fig. 1.5). Because of the limited outcrop of these rock types within the bay, the presence of the lithologies within the surficial sediment is an indication of the extent of sediment transport from an external source into the bay.

Concentrations of crystalline rocks in the sediments are highest adjacent to the Shield terrane on both the northwest and east coasts of Hudson Bay and diminish toward the centre (Fig. 4.2). Values are also moderately high (25-50%) adjacent to Paleozoic outcrop in southwestern and Proterozoic terrane in eastern Hudson Bay.

The major dispersal trends of igneous/metamorphic lithologies are eastward (offshore) from the Keewatin coast towards Hudson Strait and central Hudson Bay, and westward from crystalline outcrops on the east coast of the bay toward the Winisk Trough and Midbay Bank. Percentages between Coats and Southampton Islands are the lowest (<10%) in the area. In southern and southwestern Hudson Bay, the concentration of crystalline clasts in the sediments is variable, although there is a very general trend toward decreasing values offshore from the Nelson/Hayes and Severn Rivers.

Grey/Tan Carbonate

Paleozoic carbonate formations underlie a large part of Hudson Bay and extend onshore along the southern and southwestern coast (Fig. 1.5).

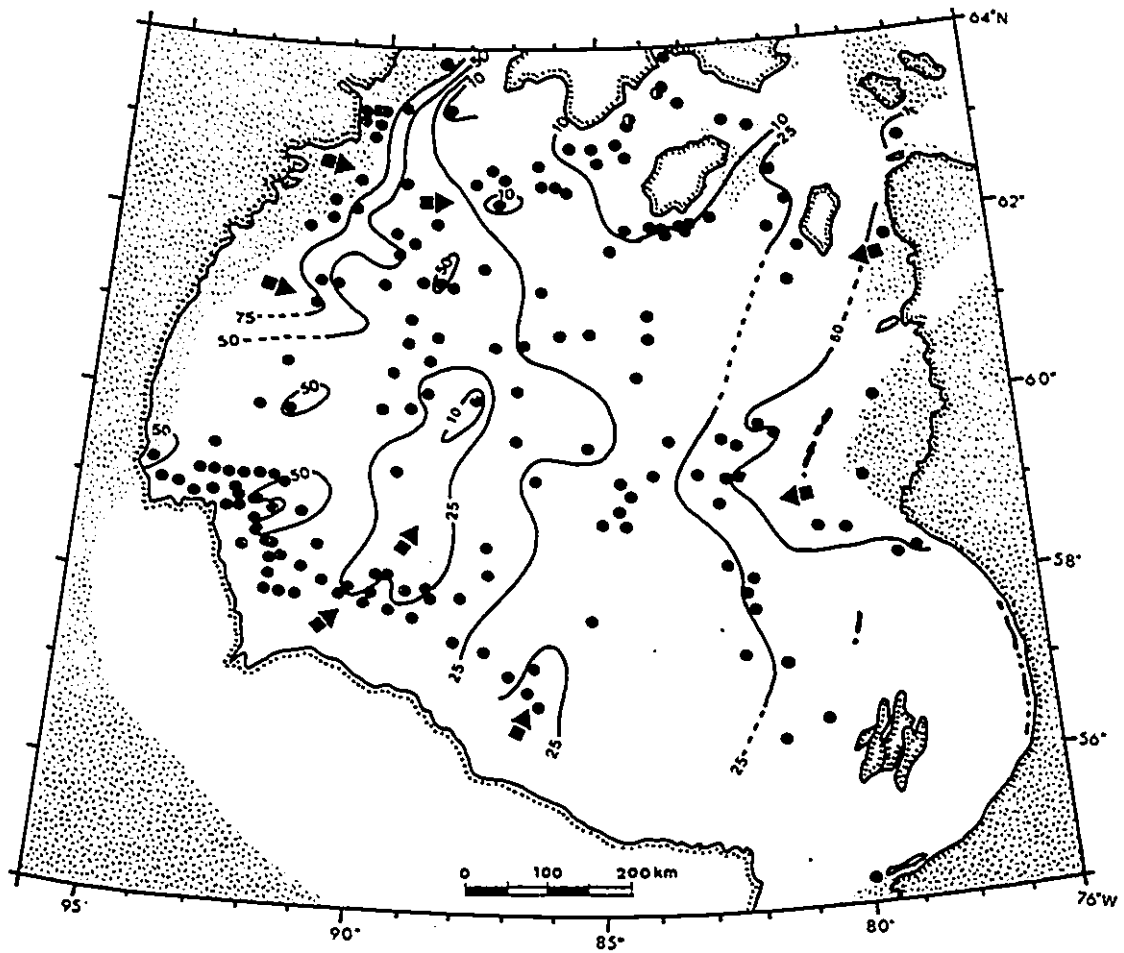


Figure 4.2: Distribution of igneous/metamorphic clasts in surficial sediments. Pattern represents outcrop area of igneous and high grade metamorphic rocks. Isopleths indicate weight percent of erratics in gravel fraction (2 - 5.6 mm), arrows denote dispersal trends.

Percentages of grey to buff to tan carbonate clasts in seafloor sediments are high in areas within the inferred limit of Paleozoic outcrop and rapidly drop off to low (<10%) or zero values in the east and west beyond this limit (Fig. 4.3). With few exceptions, the highest carbonate values are present in northern Hudson Bay, particularly Fisher Strait. Low percentages of carbonate erratics in central Hudson Bay are not solely a function of low Paleozoic input. The floor of Hudson Basin is underlain by the primarily fine-grained clastic facies of the Paleozoic Long Rapids Formation (Fig. 1.5) and, similarly, the Midbay Bank is underlain by red/pink carbonates. The fine gravel fraction of surficial sediment from these areas is enriched in these local lithologies. Consequently, percentages of Paleozoic grey carbonate are depressed. In general, the distribution of carbonate clasts is similar to that shown by Shilts (1982, p. 320).

Because the extensive carbonate source underlies Hudson Bay, variations in concentrations of Paleozoic clasts are primarily a function of dilution by other rock types. In fact, the general trend towards increasingly higher carbonate values in northern and central Hudson Bay is the inverse of the distribution of igneous/metamorphic erratics. There is no evidence for sediment transport from central Hudson Bay east or west onto the mainland.

In southern and southwestern Hudson Bay dispersal trends are not well defined. The percentage of carbonate clasts tends to decrease offshore from the Churchill, Nelson/Hayes Rivers and the intervening coastline, while carbonate concentrations increase directly offshore from the Severn River.

The distribution of grey carbonate in the fine gravel fraction of surface tills in areas adjacent to the bay is summarized by Henderson et al (1987) (Fig. 4.3). Grey/tan carbonate clasts are not present in tills along the east or west coast of Hudson Bay, north of the Seal River, Manitoba (Shilts

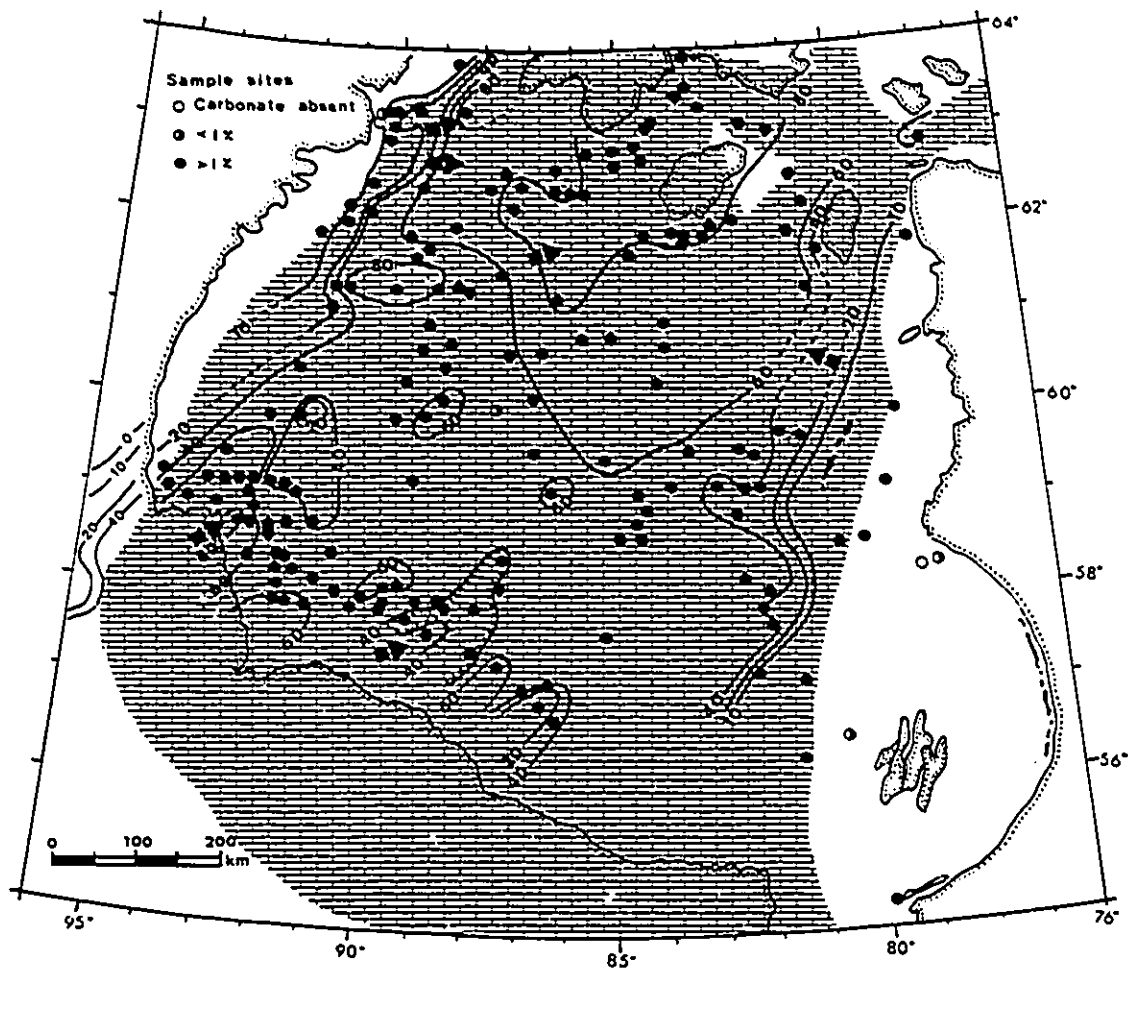


Figure 4.3: Distribution of grey to tan carbonate clasts in surficial sediments. Pattern represents outcrop area of Paleozoic carbonate formations. Isopleths indicate weight percent of erratics in gravel fraction (2 -5.6 mm), arrows denote dispersal trends. Onshore data from surface tills in Northern Ontario and Manitoba as compiled in Henderson et al (1987).

et al, 1979; Shilts, 1980a; 1986). South and southwest of the bay, high concentrations are present in surface tills of northern Manitoba and along the Winisk and Severn River systems (Kaszycki and Dilabio, 1986; Thorleifson, 1989). The southern limit of carbonate dispersal is poorly known, although the eastern extent occurs in the vicinity of the Harricana Moraine and western extent with the Leaf Rapids interlobate moraine (Fig. 1.7) (Veillette, 1986; Kaszycki, 1987).

Red/Pink Carbonates

A distinctive pink to red calcareous mudstone and siltstone is present within the fine gravel fraction of the seafloor sediments. These lithologies were recognized in the central part of the bay associated with fauna characteristic of the Devonian Williams Island Formation (Sanford, pers. comm., 1987) which outcrops beneath the bay (Fig. 4.4). The colour, softness and carbonate content distinguishes these clasts from other Paleozoic fine-grained, red to brick red, clastic rocks derived either from the Kenogami River or Leaf Rapids Formations (Sanford and Norris, 1975) or the harder, fine-grained red siltstones of the Proterozoic Dubawnt Group.

The distribution of red/pink carbonate clasts is restricted primarily to the southern and central areas of the bay (Fig. 4.4). High values (>40%) east of Midbay Bank overlie outcrops of the Williams Island Formation. The lithology is present in sediments of southern and southwestern Hudson Bay in low concentrations (<3%) and absent from samples offshore from the Knife, Churchill and Severn Rivers. Pink carbonate is also absent in sediments of eastern Hudson Bay, and, with some exceptions, the northwestern quadrant of the bay (Fig. 4.4).

Dispersal trends of red/pink carbonate clasts radiate to the northeast, east, west and southwest from the inferred source area in central Hudson Bay (Fig. 4.4). The eastern limit of these clasts in seafloor sediments coincides with the Winisk Trough in the north and Henrietta Maria Ridge in the south.

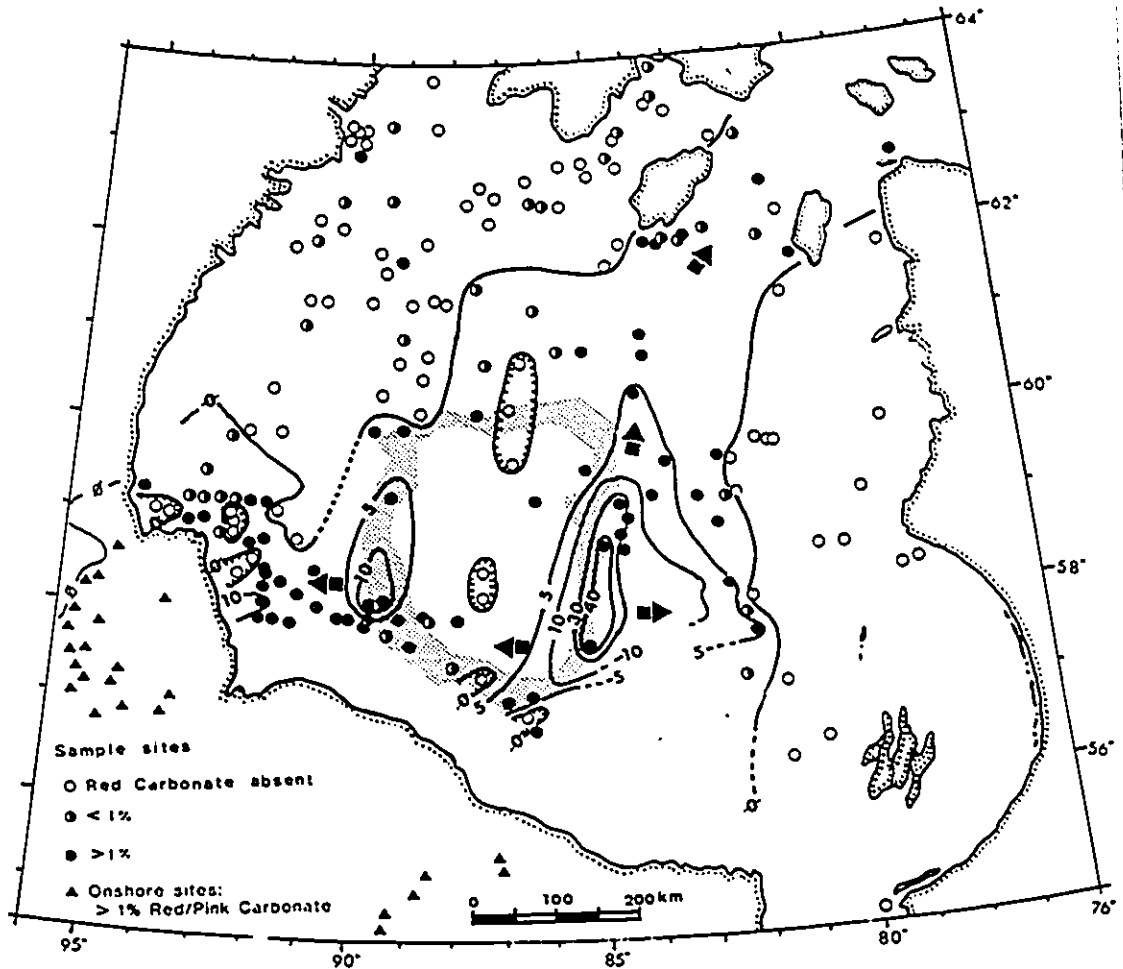


Figure 4.4: Distribution of red/pink carbonate clasts in surficial sediment. Isopleths represent weight percent in gravel fraction (2 - 5.6 mm); patterned area indicates outcrop of pink carbonate of Williams Island Formation; arrows denote dispersal trends. Onshore data from Henderson et al (1987).

Westerly dispersal extends primarily to the Hudson Basin region in central Hudson Bay and the Manitoba coast in the southwest. Several sites with low red/pink carbonate percentages are also present as far west as the Keewatin coast.

Onshore data indicate the presence of pink carbonate clasts in surface tills south and southwest of Hudson Bay (Fig. 4.4). In northern Manitoba, the westward limit of pink carbonate dispersal is coincident with the dispersal of Paleozoic grey carbonate at the Leaf Rapids interlobate moraine. No pink carbonate is present in the fine gravel fraction of tills along the west or east coast of the bay (Shilts et al, 1979).

Greywacke/Argillite

Greywacke/argillite sequences are characteristic of the Proterozoic Omarolluk Formation which outcrops on the Belcher and adjacent islands and underlies the seafloor in the Richmond Gulf (Dimroth et al, 1970; Ricketts and Donaldson, 1981). Less extensive outcrops of lithologically similar formations are present in the Sutton Inlier and Churchill areas. Minor outcrops of greywacke and argillite are also present in the Kaminak Subprovince of western Hudson Bay (Fig. 4.5).

Greywacke/argillite clasts are distributed primarily in the sediments of eastern and southern Hudson Bay (Fig. 4.5). Highest values (60-73%) occur in deposits on or near the inferred outcrop area of the Omarolluk Formation, with a general decrease in the portion of greywacke clasts towards the west, north and northwest. Low percentages in sediments overlying and adjacent to the Midbay Bank may be a function of dilution by high pink carbonate percentages in this area. In general, the distribution is similar to that obtained by Shilts (1982, p. 321).

The continuous presence of greywacke clasts across the eastern and southern bay, high percentages in deposits adjacent to the Belcher Islands, and trend towards decreasing values with distance from this outcrop area, suggests that the provenance of

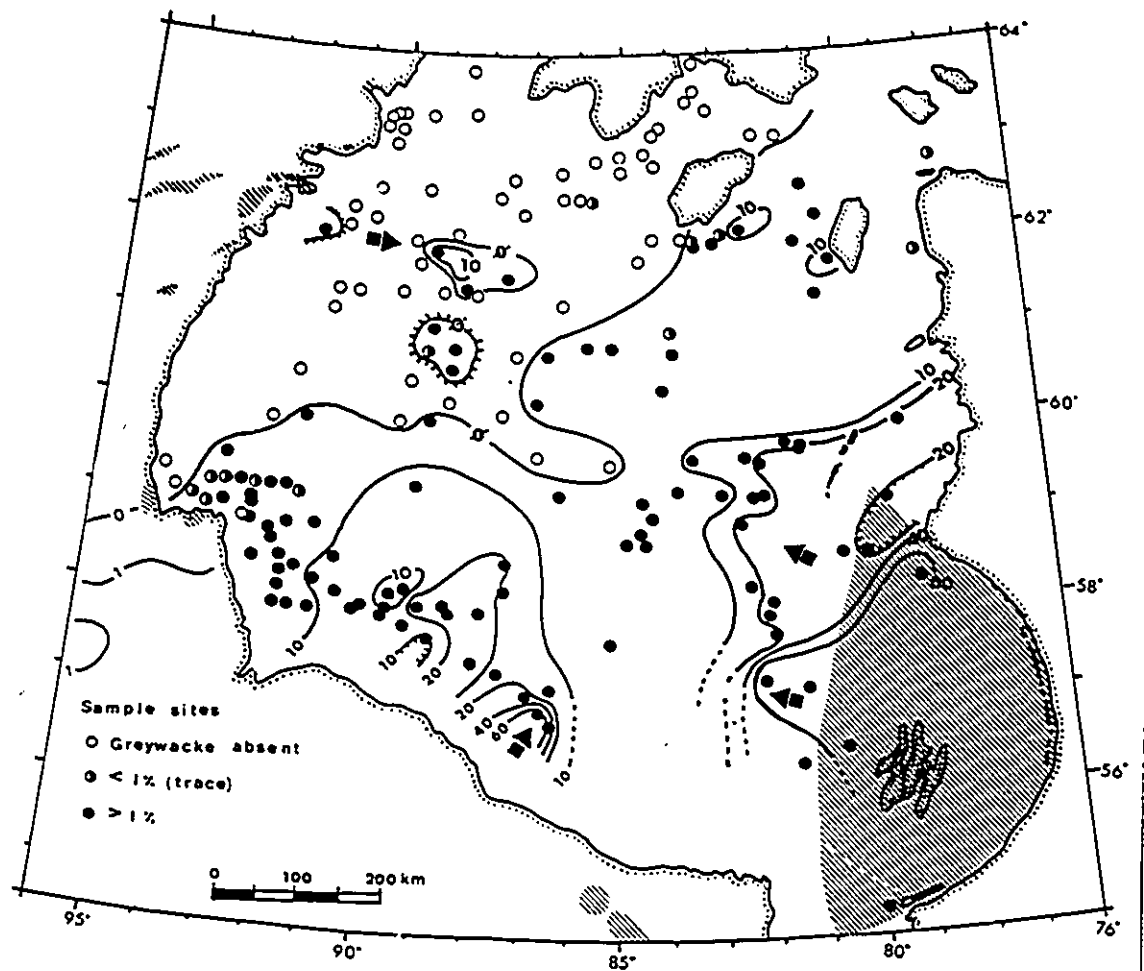


Figure 4.5: Distribution of greywacke/argillite clasts in surficial sediment. Isopleths represent weight percent in gravel fraction (2 -5.6 mm); pattern indicates outcrop area of Proterozoic basins which include greywackes and/or argillites; arrows denote dispersal trends. Onshore data from Henderson et al (1987).

these greywackes is primarily related to the outcropping of the Omarolluk Formation in the Richmond Gulf area. Possible sediment contribution from the Sutton Inlier is indicated by higher percentages in sediment directly offshore from the Severn River. In western Hudson Bay, several isolated areas with significant accumulations of greywacke erratics are present and may be related to outcrops in the Kaminak Subprovince, although petrographic examination of clasts from this area and the vicinity of the Belcher Islands reveals no significant differences in texture or composition (Fig. 4.5).

Dispersal trends of greywacke/argillite clasts from the Richmond Gulf area indicate sediment transport to the northwest and west. The western limit of dispersal is similar to that of red/pink carbonate clasts, and extends to Coats Island, Hudson Basin and the northern Manitoba coast. Greywacke erratics present in sediments of the northwestern quadrant of the bay may indicate an extension of the primary dispersal trend or, eastward sediment transport from a source in the District of Keewatin. Dispersal trends offshore from the Severn River suggest northward transport and imply a greywacke source south of the bay, possibly glacial sediments and/or rocks from the Sutton Inlier.

Onshore, greywacke clasts are present in the fine gravel fraction of surface tills south and southwest of Hudson Bay and on Coats and Mansel Islands (Aylsworth and Shilts, in press). The northern limit of greywacke dispersal on the west coast of the bay is coincident with carbonate limits near the Seal River, Manitoba (Fig. 4.5) (Shilts, 1980a, 1982; Henderson et al, 1987).

Dubawnt Lithologies

Lithologic characteristics of the Dubawnt Group were described in Chapter 1. Some Paleozoic formations are similar in colour and texture, so identifications were limited to definitive rock types from the Dubawnt Group.

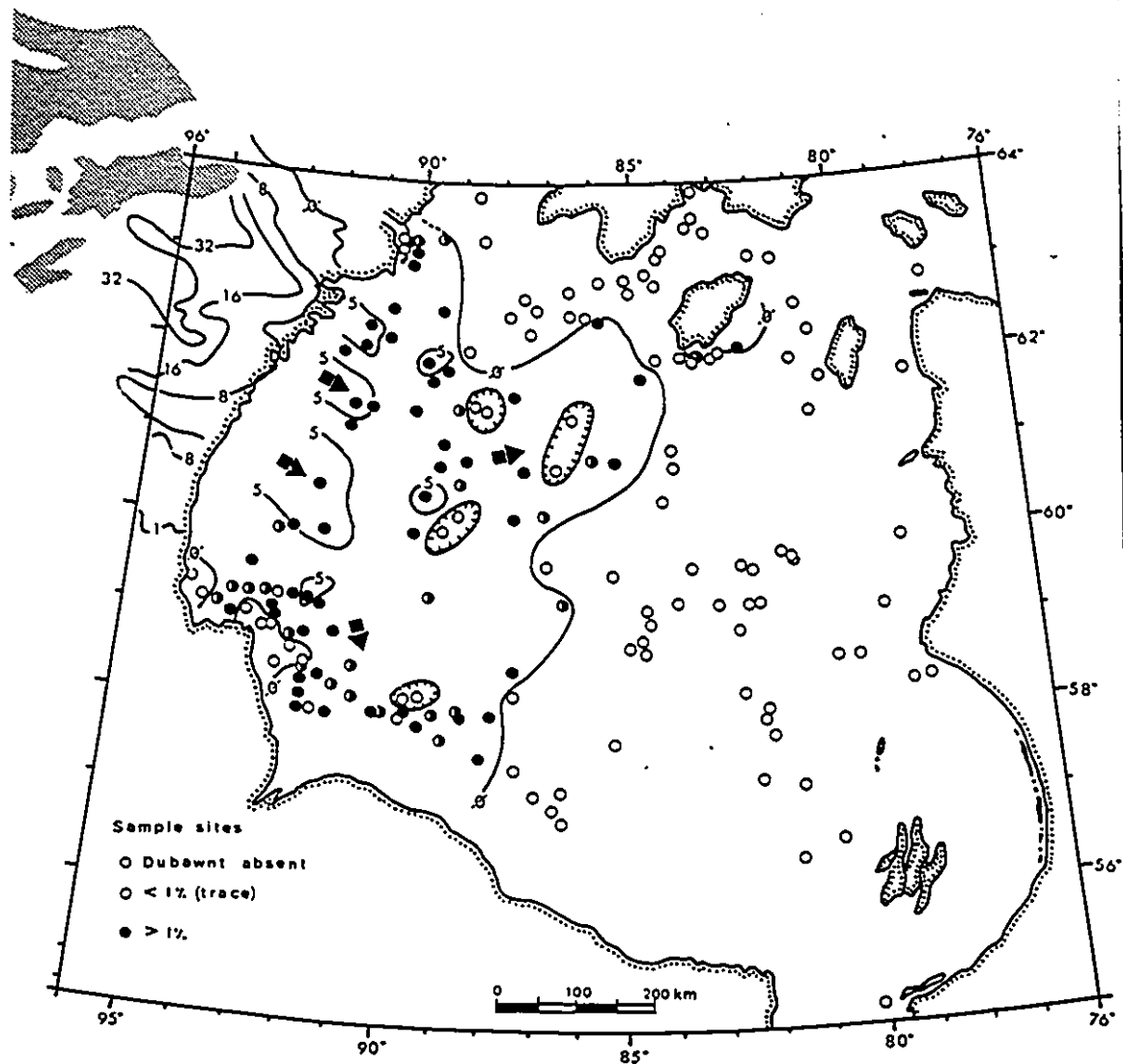


Figure 4.6: Distribution of Dubawnt Group clasts in surficial sediment. Isopleths represent weight percent in gravel fraction (2 -5.6 mm); pattern indicates outcrop area of Proterozoic Dubawnt Group; arrows denote dispersal trends. Onshore data from Kaszycki and Shilts (1979).

The distribution of Dubawnt clasts is restricted to deposits in western and southwestern Hudson Bay (Fig. 4.6). Dubawnt erratics are absent from sediments collected in the northwest and Fisher Strait. South of Coats Island values are generally low (<1%). The highest percentages (7-15%) occur along the western coast offshore from the outcrop area. In southwestern Hudson Bay, values are generally low (<3%) and no Dubawnt erratics were found in samples collected directly offshore from the Churchill, Knife and Nelson/Hayes Rivers. The dispersal trend of Dubawnt lithologies is towards the east, similar to trends observed in igneous/metamorphic erratics, and toward the southeast, extending as far east as the Hudson Basin and Ontario coast between the Nelson/Hayes and Severn Rivers.

Onshore, a well defined dispersal train is present in the District of Keewatin extending from the outcrop area (Kaszycki and Shilts, 1979). No Dubawnt erratics are present in surface tills south and east of Hudson Bay, although they have been reported from tills exposed along the Nelson River (Nielsen et al, 1986) and on Coats Island (Aylsworth and Shilts, in press).

4.4.2. Interpretation of Dispersal Trends

The distribution of Dubawnt, greywacke/argillite, and red/pink carbonate clasts in the sediments is shown in Fig. 4.7. These rocks have a restricted provenance and, therefore, are more sensitive indicators of sediment transport than carbonate or igneous/metamorphic rock types. The occurrence of Dubawnt, greywacke/argillite, and red/pink carbonate erratics appears to overlap in a zone which includes Hudson Basin and extends NE-SW across the bay. Dispersal trends indicate a complex picture of sediment transport dominated by four main directions: 1) east, northeast and southeast from the Keewatin coast; 2) west and northwest from the Richmond Gulf area and Quebec coast; 3) eastward as well as westward and northward from the Midbay Bank; and, to a lesser extent, 4) offshore trends in southern and

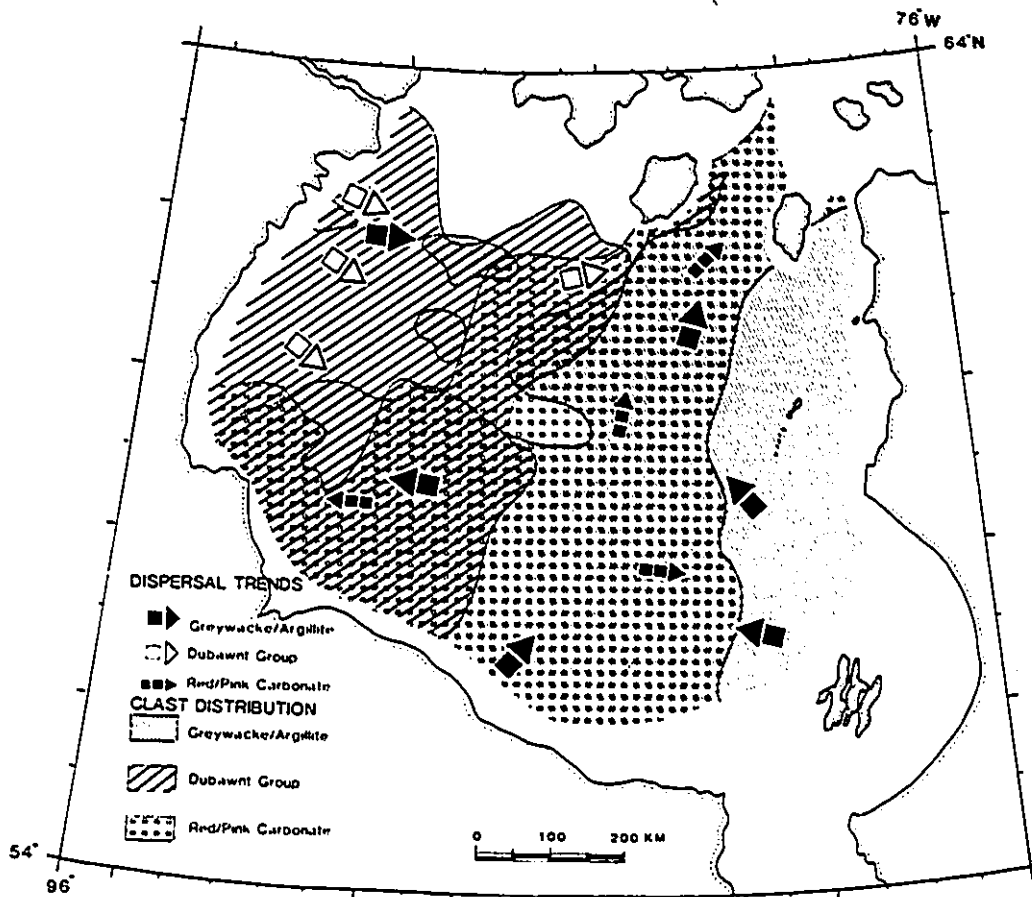


Figure 4.7: Relationship between distribution and dispersal trends of Dubawnt Group, greywacke/argillite and red/pink carbonate clasts in seafloor sediments.

southwestern Hudson Bay. There is no evidence for dispersal of sediment from Hudson Bay east or west onto the mainland.

1) East, northeast and southeast from the Keewatin Coast

The dispersal trend of igneous/metamorphic and Dubawnt lithologies in northwestern Hudson Bay indicates sediment transport east and northeast towards Hudson Strait. This trend may also be represented by the dispersal of greywacke from a source in the Kaminak Subprovince. Although offshore dispersal of fine gravel by sea-ice or fluvial transport during pre-Quaternary or Quaternary low sea level stands undoubtedly occurred, there is strong evidence to suggest that sediment transport and deposition in this area is controlled primarily by glacial processes:

- a) the dispersal trends oppose the dominant current direction in the bay,
- b) the distribution of Dubawnt erratics within the bay appears to extend from the dispersal train defined from till samples onshore in both concentration and direction (Fig. 4.6).
- c) Dubawnt lithologies are present in tills of Coats, but not Mansel Islands, indicating that glacier ice from a Keewatin source extended across the northern part of Hudson Bay (Aylsworth and Shilts, in press).
- d) The increase in carbonate and decrease in crystalline content towards the east suggests carbonate enrichment through erosion of underlying carbonate bedrock and/or decreasing dilution effects from sediment transported into the bay. These observations are compatible with glacier flow toward the east.
- e) In the southeast, the dispersal of Dubawnt erratics extends to the Ontario coast between the Nelson/Hayes and Severn Rivers (Fig. 4.6). The interpretation of glacial transport of sediment implies that ice from a Keewatin Centre must have covered western Hudson Bay and parts of the Hudson Bay Lowlands at some time. The presence of Dubawnt lithologies in the lowermost till (Sundance Till) exposed

along the Nelson River supports this hypothesis (Nielsen et al, 1986).

2) West and northwest from the Richmond Gulf and Quebec coast

The dispersal of greywacke/argillite and, to a lesser extent, igneous/metamorphic erratics indicates sediment transport westward and northwestward from source areas in the Richmond Gulf and along the Quebec coast. The inference that greywackes are derived primarily from the Omarolluk Formation of the Proterozoic Belcher Island Group is based on the magnitude of the dispersal, the recognition of concretions characteristic of the Omarolluk Formation at some sites, and the extensive outcrop area of the formation compared with greywacke outcrops in the District of Keewatin, Sutton Inlier and Churchill areas.

Evidence supporting dispersal of greywacke and igneous/metamorphic erratics from the east side of the bay by glacial processes includes the following:

- a) the presence of greywacke and Omarolluk erratics within tills exposed along the rivers of the Hudson Bay lowlands and the surface till of Manitoba (Henderson et al, 1987; Thorleifson, 1989). These tills were deposited by ice flowing west to southwest and indicate that sediment of eastern provenance was transported by ice across southern Hudson Bay.
- b) the presence of greywacke in tills of both Coats and Mansel Islands (Aylsworth and Shilts, 1988) indicates glacial transport north and northwest toward Hudson Strait from a source area on the eastern coast of the bay.
- c) the westward dispersal of greywacke erratics from the Richmond Gulf area is counter to the present current regime in the bay.

3) Eastward, westward and northward from Midbay Bank

Westward and northward transport of red/pink carbonate erratics from a source area in central Hudson Bay can be explained by ice flow from a centre east of the Richmond Gulf

area as discussed above. Eastward transport of sediment eroded from the Midbay Bank is not evident in the distribution of any other lithologic group.

Although sea-ice rafting has been proposed as a mechanism for gravel transport to offshore areas, it appears unlikely in this case. The close association of high percentages of pink carbonate clasts in sediments overlying the outcrop area of the Williams Island Formation indicates that seafloor sediment is derived primarily from erosion of underlying bedrock (Fig. 4.4). Because the outcrop area is completely submerged, the material could not have been incorporated into sea-ice. This implies sedimentation by glacial processes in central Hudson Bay.

High concentrations of pink carbonate erratics are present in the uppermost tills along the Winisk River. This till has been interpreted as deposited from an ice stream flowing south from Hudson Bay and localized in the Winisk Trough and Winisk River Valley (Wyatt, 1987; Thorleifson, 1989). It is probable that the limited eastward dispersal of pink carbonate erratics from the Midbay Bank may post-date the glacial maximum and be related to this re-orientation of iceflow.

4) Offshore trends in southern and southwestern Hudson Bay

Offshore dispersal trends in southern and southwestern Hudson Bay are localized and poorly defined. The most pronounced are indicated by the distribution of grey carbonate erratics offshore from the Churchill and Nelson/Hayes Rivers. Similar trends offshore from the Severn River are shown by the distribution of greywacke/argillite and igneous/metamorphic clasts. The association of these trends with the major rivers of southern Hudson Bay suggests that sediment transport may be controlled by these rivers during periods of high discharge. Except for grey carbonates, few local sources for these erratics are present in the Hudson Bay Lowlands other than Quaternary sediments exposed along the river banks (Nielsen et al, 1986; Thorleifson and Wyatt, 1987). Erosion of these deposits by the rivers would

provide sediment of mixed composition representing an amalgamation of all eroded glacial material (Adshead, 1983a,b,c).

4.5. Heavy Mineral Analysis

Although individual minerals are rarely diagnostic of provenance, certain suites of heavy minerals can be characteristic of specific bedrock lithologies. Depending on such factors as rate of erosion, variations in bedrock composition and the degree of mixing during sediment transport and deposition, these heavy mineral assemblages may be modified to varying degrees. Consequently, similar suites may be produced in unlike ways. The significance of heavy minerals, therefore, must be evaluated within the geological and sedimentological framework of the region.

As outlined earlier, the Hudson Bay area is characterized by three fundamentally different geological terranes (Fig. 1.5). Heavy mineral suites common to the rock types within these terranes are outlined in Hubert (1971, p.462) and Pettijohn (1957, p.513) among others and summarized in Table 4. Specific heavy mineral suites have also been described from the analysis of till within the dispersal trains of distinctive erratics (Paré, 1982; Thorleifson, 1989). Based on these data, heavy mineral suites characteristic of the various geological terranes surrounding Hudson Bay are also summarized in Table 4.

4.5.1. Heavy Mineral Assemblages

In Hudson Bay, the heavy mineral analyses (Appendix F) indicate distinct variations in the relative percentages of the major mineral species. The regional distribution of the more abundant (>10%) heavy minerals is shown in Figure 4.8. Through changes in the relative abundance and the presence or absence of certain minerals, five mineral assemblages (named according to the dominant minerals), at times overlapping, were recognized. With the exception of siderite, these minerals and assemblages

TABLE 4

CHARACTERISTIC HEAVY MINERAL SUITES FROM MAJOR GEOLOGICAL TERRANES, HUDSON BAY.

General Suite (Hubert, 1971 Pettijohn, 1956)	Specific suites in Quaternary Sediments	
	(Paré, 1982)	(Thorleifson, 1989)
<u>Archean/Proterozoic Terrane</u> Igneous and high grade metamorphic rocks of the Churchill and Superior Structural Province		
	N. of Chesterfield Inlet	Hudson Bay Lowlands
Garnet Epidote Kyanite Staurolite Monazite Ilmenite Titanite	Garnet Epidote Titanite Zircon	Garnet Epidote Ilmenite Pyrite
	S. of NWT/Man. border	
	Garnet Orthopyroxene Ilmenite	
	Ontario (Sup. Prov.)	
	Garnet Orthopyroxene Titanite	
<u>Proterozoic Basins</u> Mafic and ultramafic volcanic rocks Metasedimentary rocks (sandstones, carbonates, iron formation)		
Mafic volcanics Orthopyroxene Ilmenite Augite Leucoxene Rutile Metaseds. (related to source) Hematite (iron fm)	District of Keewatin (Dubawnt Zone) Hematite Epidote Pyrite	Hudson Bay Lowlands Hematite Orthopyroxene Epidote Ilmenite
<u>Paleozoic</u> Predominantly carbonates, minor shale, sandstone and evaporites		
Reworked seds. Leucoxene Zircon (rounded)		Grey carbonate Siderite Garnet (?) Pyrite (?) Red carbonate Garnet (?) Hematite(?)

can be related to Precambrian geological terranes adjacent to and underlying the bay.

I Epidote-Orthopyroxene-Garnet:

This mineral assemblage occurs in all sediment types in the deeper parts of the bay including the Winisk Trough, Hudson Basin and between Coats and Mansel Islands, as well as offshore from the Ungava Peninsula and central District of Keewatin. The mineral suite may also include ilmenite and/or titanite and is characteristic of igneous and metamorphic rocks of the Shield terrane surrounding a good part of the bay (Table 4). The suite is present to some degree at all sample sites and can be related only generally to the extensive outcrop of igneous and metamorphic rocks surrounding the bay rather than to a specific source area.

II Garnet-Orthopyroxene:

An assemblage dominated by garnet and orthopyroxene and including epidote, titanite and ilmenite is present in the predominantly coarse-grained sediments of northwestern Hudson Bay, including Fisher Strait and Roes Welcome Sound as far south as Rankin Inlet. Sediments dominated by garnet are limited to this northern area and parts of the Midbay Bank. The mineral suite is characteristic of igneous and metamorphic rocks, especially gneisses and schists; lithologies which are common onshore in the District of Keewatin. Surface tills northwest of Chesterfield Inlet are also composed of a garnet-rich (garnet-epidote-titanite) assemblage (Paré, 1982) (Fig. 4.8).

Eastward from the Keewatin coast, the relative abundance of heavy minerals shifts from predominantly garnet to predominantly orthopyroxene. Orthopyroxene (hypersthene) and ilmenite are both typical minerals of granulite grade metamorphic rocks (Deer et al, 1966). Gneisses outcropping on the mainland and near Coral Harbour, Southampton Island, and the anorthosite of Walrus Island in Fisher Strait are all metamorphosed to this grade

(Heywood and Sanford, 1976). The relative increase in abundance of orthopyroxene in Fisher Strait suggests enrichment from these local sources. The dominant direction of sand transport in the area appears to be eastward from the shield terrane on the west coast and across the Paleozoic formations underlying the bay.

III Epidote-Garnet-Hematite:

An assemblage composed of epidote, garnet, and hematite, with local enrichment by ilmenite, orthopyroxene, pyrite and titanite occurs in three regions: 1) northwest Hudson Bay, offshore from the Keewatin Coast to Coats Island, 2) offshore from the Belcher Islands, and 3) south and southwest Hudson Bay including the Midbay Bank. The association of epidote and hematite suggests the heavy mineral suite is derived primarily from Proterozoic sedimentary and volcanic rocks, although the heavy minerals garnet, ilmenite and titanite show input from igneous and metamorphic sources, as well (Table 4).

This mineral assemblage is essentially defined by the proportion of hematite in the sediments, since concentrations exceeding 10% are the only feature distinguishing the assemblage from others in the bay (Fig. 4.9). Specific sites of hematite enrichment ($\geq 10\%$) are, with few exceptions, associated with the coarse sediment types (Fig. 4.10). The general lack of an obvious relationship between hematite abundance and depth (assuming depth is the major factor influencing seafloor physio-chemical conditions) suggests that the mineral distribution is related primarily to sediment source. Localized hematite enrichment in sands may be associated with sorting processes.

In northwestern Hudson Bay, mineral assemblage III is similar to the Dubawnt Zone assemblage defined onshore by Paré (1982) (Fig. 4.8). Tills down-ice from the Dubawnt Group are characterized by high concentrations of unaltered, steel grey, subangular to round hematite (Paré, 1982; Kaszycki and Shilts, 1980). Grains of similar aspect are also observed on the seafloor. The coincidence in both the mineral assemblage and

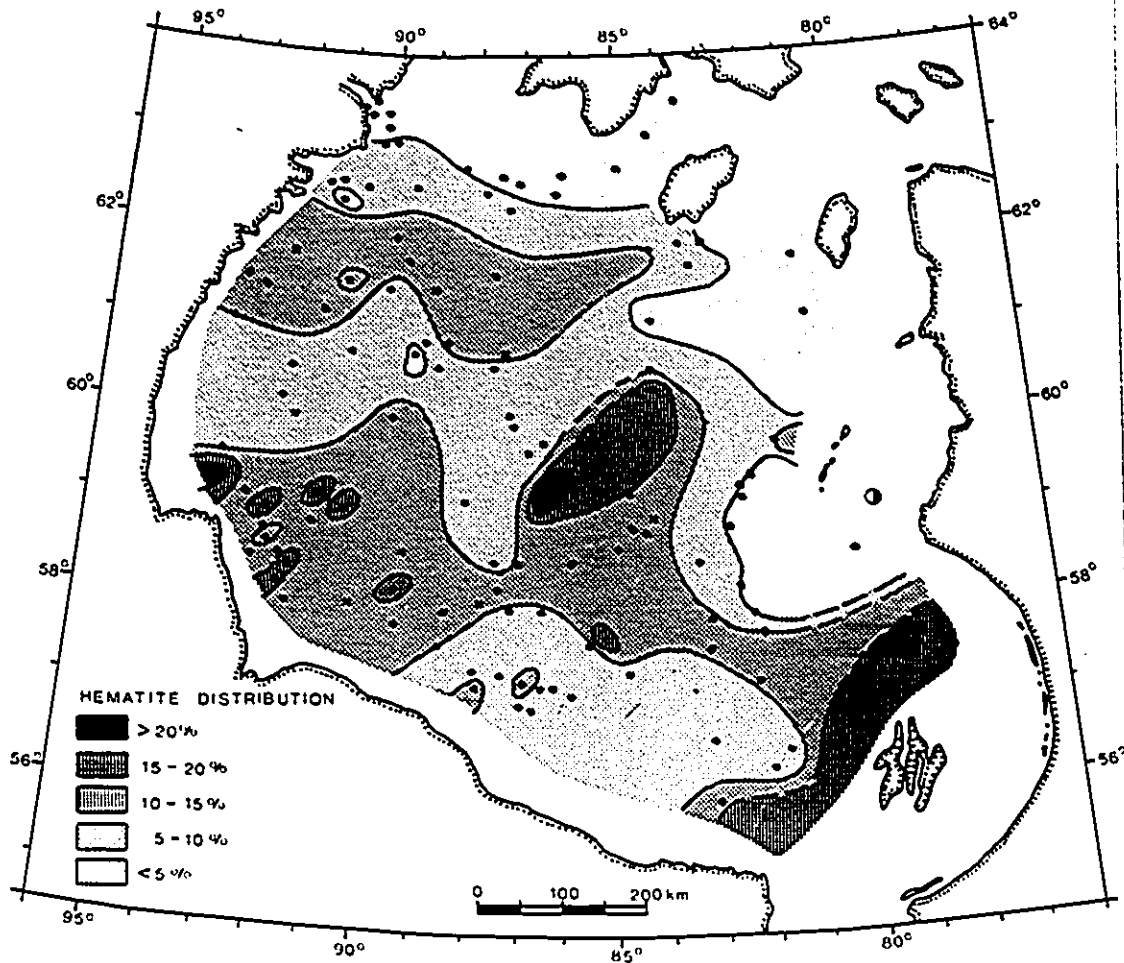


Figure 4.9: Hematite distribution in Hudson Bay. Contoured areas represent weight percent hematite of non-magnetic heavy mineral fraction.

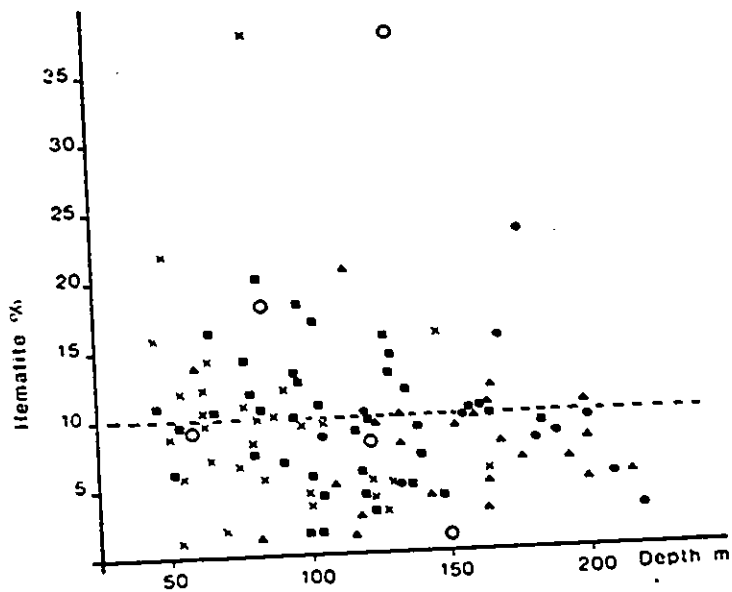


Figure 4.10: Plot of hematite concentrations vs depth. No obvious relationship is present between variables and/or sediment type. Dashed line represents 10% hematite, the limiting factor used to delineate heavy mineral assemblages. Symbols for sediment types are given in Figure 4.8.

aspect of the hematite offshore and onshore, in the District of Keewatin, implies that the composition of the offshore surficial material in the area is strongly influenced by Dubawnt provenance and suggests that the main dispersal trends in that part of the bay are from west to east.

Assemblage III is also found offshore from the Belcher Islands. Although hematite in this area has a similar aspect to that described from Dubawnt sources, it is undoubtedly derived from the adjacent Proterozoic outcrops in the Richmond Gulf. This underlines the difficulty in characterizing a specific source on grain aspect alone. The heavy mineral suite is similar to that found in tills exposed along the Severn River in the Hudson Bay Lowlands, which are enriched in erratics of Omarolluk greywackes characteristic of the Belcher Island Group (Thorleifson, 1989). Assemblage III, in this area, suggests westward sediment transport from the outcrop area in southeastern Hudson Bay.

The epidote-garnet-hematite assemblage is also present in the sediments of southern and southwestern Hudson Bay, including the Midbay Bank, although the relative abundance of the minerals varies. The distribution of the assemblage and the association with gravel clasts derived from the Proterozoic basins indicates sediment transport westward from the Belcher Island Group, or southeastward from the Dubawnt Group, or both (Fig. 4.8).

In detail, the relationship between hematite concentrations and the abundance of Proterozoic erratics (as represented by the combined percentage of Dubawnt and greywacke clasts) is poorly defined (Fig. 4.11). For low erratic percentages (<30%), hematite concentrations (>10%) show a tendency to decrease with increasing Proterozoic abundance. In southern Hudson Bay particularly, hematite values increase westward (Fig. 4.9) unlike the dispersal trends of greywacke (Fig. 4.5) and Dubawnt Group erratics (Fig. 4.6). Similarly, sites over the Midbay Bank have high hematite but low greywacke abundances.

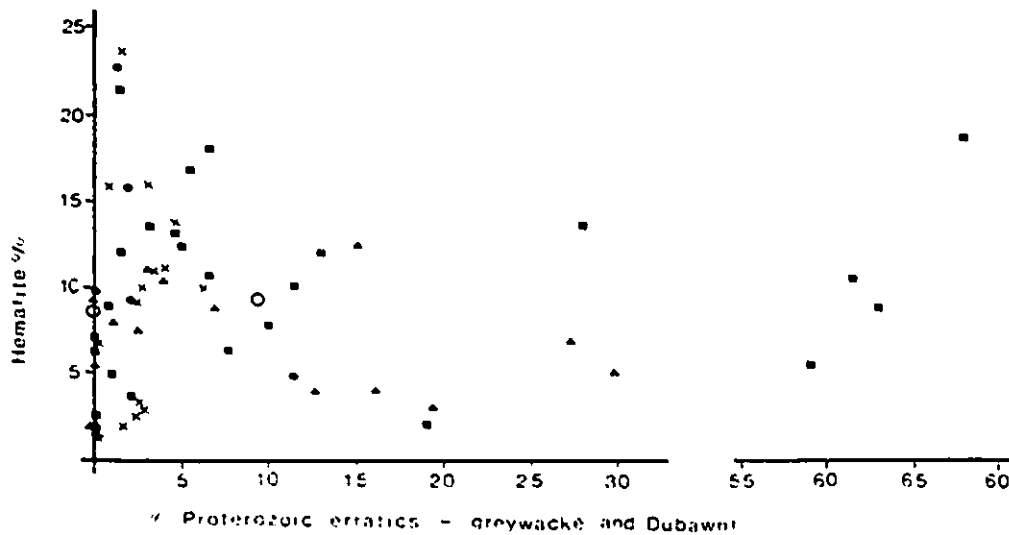


Figure 4.11: Relationship between concentrations of hematite and Proterozoic erratics in surficial sediment. For low erratic percentages, hematite concentrations increase as the proportion of Proterozoic erratics decrease. This relationship is the inverse for high percentages of Proterozoic erratics. Symbols for sediment types given in Figure 4.8.

The absence of a strong relationship between the two variables (Fig. 4.11) is not inconsistent with sedimentation by glacial processes. Linden (1975) concluded from a dispersal study in tills in Sweden that the coarser fractions tend to be dominated by local debris while finer-grained fractions contain material transported further. Consequently, an increase in the proportion of hematite may be expected in the southwest quadrant of Hudson Bay assuming derivation of the mineral through glacial transport and comminution of Proterozoic rock outcropping along the eastern coast and in the District of Keewatin. Difficulties arise in isolating the comminution processes from local factors affecting mineral abundance in a large area like Hudson Bay.

Over the Midbay Bank, hematite and locally-derived pink carbonate erratics are abundant (Figs. 4.9 and 4.4), while the percentage of Proterozoic greywacke clasts is low (Fig. 4.5). Thorleifson (1989) also found a positive correlation between hematite and pink carbonate erratics in tills south of the bay (Table 4). This implies that the Paleozoic Williams Island Formation underlying the Midbay Bank may be a hematite source. Lithologic descriptions of the formation (Sanford and Norris, 1975) and visual examinations of the larger clasts indicate that these rocks do not contain sand-sized hematite and are an unlikely source. Therefore, it is postulated that hematite in the heavy mineral suite is derived from Proterozoic sources with the gravel fraction dominated by the locally-derived carbonate lithologies which generally lack a heavy mineral component. The apparent association of hematite and red/pink carbonate clasts is a function of the multiple provenance of the sediment.

IV Orthopyroxene-Epidote-Garnet:

On the eastern side of Hudson Bay, an area encompassing northern Richmond Gulf westward to the Winisk Trough is characterized by the heavy mineral assemblage orthopyroxene, epidote, garnet, and, commonly, ilmenite. Both orthopyroxene and ilmenite are characteristic minerals of mafic volcanic rocks (Table 4).

The major source of this assemblage is most likely the mafic to ultramafic volcanic rocks of the Circum-Superior Belt which crop out on the Ottawa and Sleeper Islands in eastern Hudson Bay (Baragar and Lamontagne, 1980). Granulite grade metamorphic rocks of the Superior Province, enriched in orthopyroxene, also outcrop on the adjacent mainland (Herd, 1978). Offshore from the eastern coast of the bay, the heavy mineral composition changes gradationally southward. The increase in hematite abundance is most likely directly related to an increase in the proportion of material derived from the metasedimentary rocks within the Belcher Island Group. This implies sediment transport to the west, directly offshore from the Precambrian source rocks.

Assemblage IV is also present offshore from the Severn River. In this small area, hematite values are depressed and the heavy mineral assemblage is dominated by orthopyroxene, garnet and epidote. The abundance of orthopyroxene suggests sediment input from a mafic source that could be related to the Proterozoic mafic volcanic and sedimentary rocks of the Sutton Inlier, which outcrop downstream and to the east. This conclusion implies offshore sediment transport.

V Siderite:

A mixed assemblage characterized by the presence of siderite extends offshore from the mouth of the Nelson/Hayes River estuary into central Hudson Bay. Since siderite may be the only distinctive heavy mineral derived from a source within the bay, its distribution in the marine sediments, as well as other deposits surrounding Hudson Bay, has important implications for the interpretation of the processes of sediment transport and deposition.

4.5.2. Siderite Distribution and Provenance

Siderite is widely distributed in the heavy mineral fraction of tills, fluvial and marine sediments of Hudson Bay and adjacent areas (Fig. 4.12).

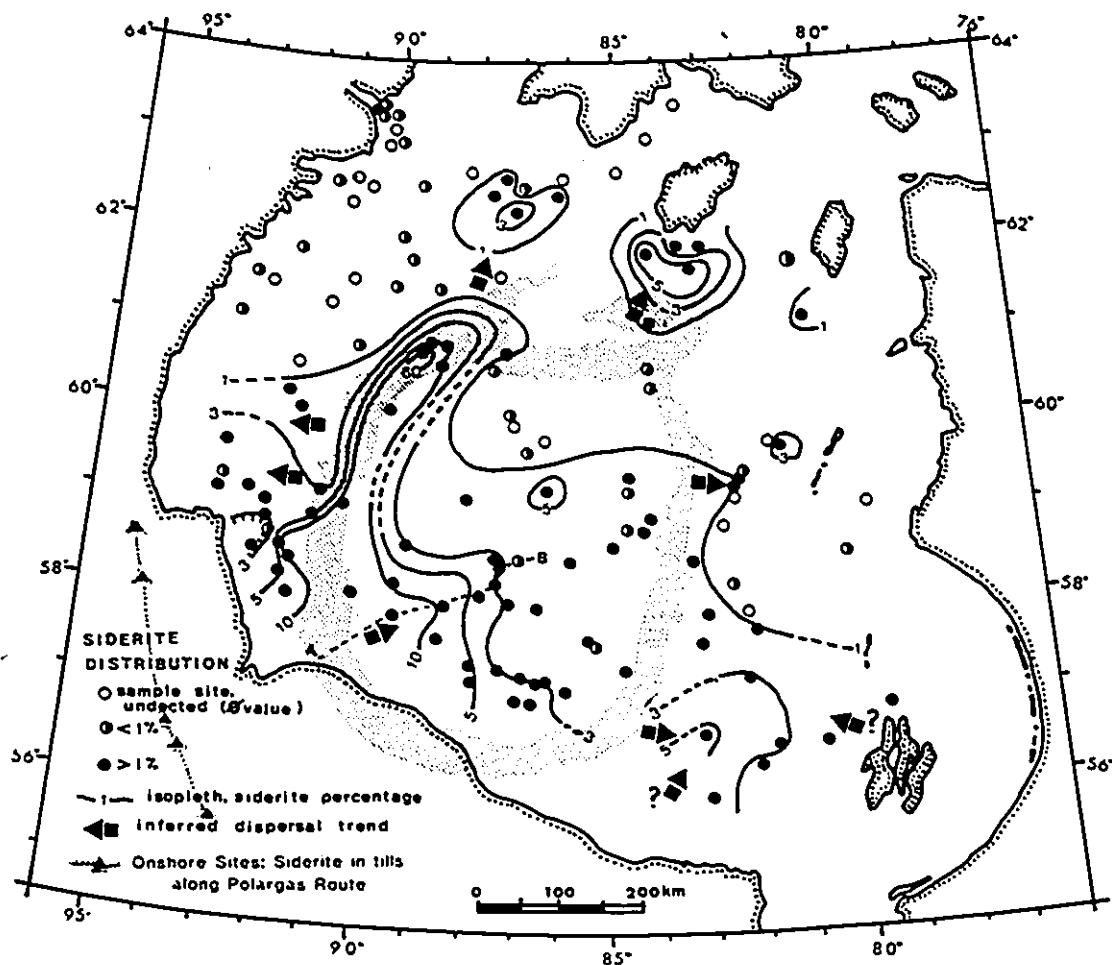


Figure 4.12: Distribution of siderite. Isopleths indicate weight percent in non-magnetic heavy mineral fraction; pattern represents outcrop area of Devonian Kwataboheagan and Stopping River Formations; arrows denote probable dispersal trends. Onshore data from Shilts (1980b), Paré (1982), and Thorleifson (1989).

Skinner (1973) first reported siderite in tills of the James Bay Lowlands. In the Hudson Bay Lowlands, the mineral is present in the heavy mineral fraction of tills exposed along the Nelson River (E. Nielsen, personal comm., 1987), the Severn and Winisk Rivers in association with high concentrations of grey and buff carbonate in the gravel fraction (Wyatt, 1987; Thorleifson, 1989), and a portion of the proposed natural gas pipeline, west of Hudson Bay (Shilts, 1980b; Paré, 1982) (Fig. 4.12). It is also present in the sediments of the Severn River (Adshead, 1983). In northern Hudson Bay, Paré (1982) found siderite values >13% in tills on Coats Island.

Within Hudson Bay, siderite percentages are generally low (<5%) but vary regardless of depth or sample type (Fig. 4.13). With few exceptions, higher concentrations (>5%) are associated with coarse-grained sediments, particularly sandy diamictons and, to a lesser extent, sorted sands. Highest values (>25%) are confined to sample sites directly overlying the outcrop area of the Devonian Kwataboahegan and Stooping River Formations (Sanford and Norris, 1975) (Fig. 4.12). Siderite is distributed primarily in the southern and western parts of the bay, although high values are also present in southwestern and south central Hudson Bay and isolated areas south of Southampton and Coats Island. Because the mineral distribution is restricted to specific areas of the bay and does not appear related to either texture or depth, the primary control must depend on sediment source.

Skinner (1973) concluded that siderite in tills in the James Bay Lowlands was reworked from Devonian carbonate rocks. Similarly, the source of the mineral in tills of the Hudson Bay Lowlands and seafloor sediments of Hudson Bay has been attributed to the Devonian Stooping River and Kwataboahegan Formations where the mineral is known to occur as fracture and cavity fillings (Sanford and Norris, 1975; Shilts, 1980b; Paré, 1982; Henderson, 1983a,b). These formations outcrop on the

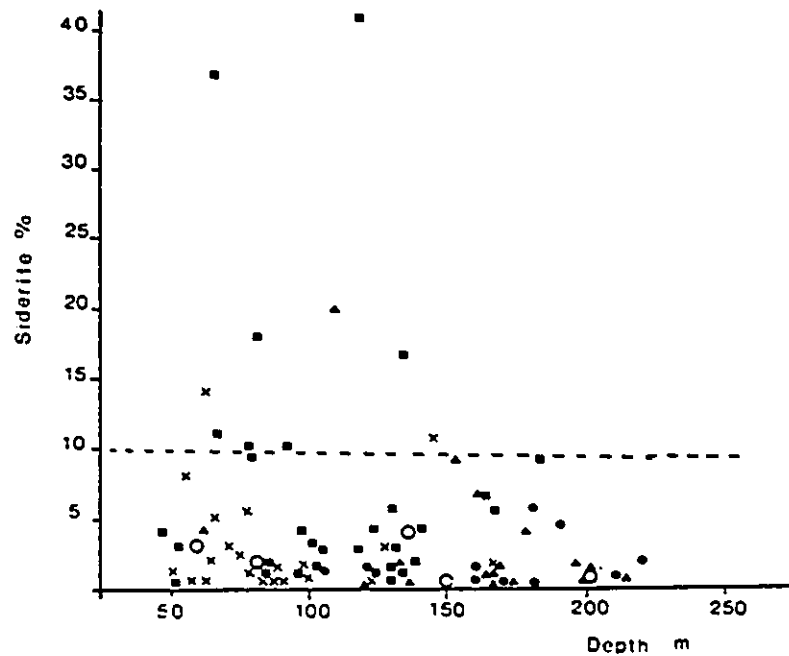


Figure 4.13: Plot of siderite concentration, sediment type and depth. Although high siderite concentrations (>5%) are most common in coarser-grained sediment types, no obvious relationship is present among variables. Ten percent (10%) siderite, shown by the dashed line, is the arbitrary value used to define heavy mineral assemblages. Symbols for sediment types are given in Figure 4.8.

southwestern shore of the bay between the mouths of the Nelson and Severn Rivers and extend under the bay in an annular outcrop pattern (Fig. 4.12). The association between siderite and carbonate clasts in the tills of the Hudson Bay Lowlands (Thorleifson, 1989) and the striking coincidence of high siderite concentrations in the seafloor deposits overlying the Stopping River and Kwataboahagan Formations in Hudson Bay is compelling evidence in support of the Devonian formations as the principle source of the siderite. Nevertheless, it is possible that the mineral is derived from other or additional source areas.

Siderite is also known to occur in the cherty and carbonate facies of the Proterozoic iron formations of the Belcher Islands (Jackson, 1960) and Richmond Gulf (Chandler, 1984). Although there are some definite colour and textural differences in siderite grains in seafloor sediments, no obvious correlation exists between grain morphology and distribution, which suggests a single dominant source. Nevertheless, slightly elevated siderite values present in sediments adjacent to the Belcher Islands may reflect a minor contribution from the adjacent Proterozoic terrane.

The possibility of authigenic formation of siderite within the sediments has been considered and rejected on the basis of the physio-chemical conditions necessary for formation, the fairly limited distribution of siderite within the bay and the widespread occurrence of the mineral in tills surrounding the bay (Paré, 1982; Adshead, 1983a). Siderite forms in a reducing environment rich in organic matter, such as stagnant basins or estuarine environments (Garrels and Christ, 1965). These conditions exist presently in the Hudson Bay Lowlands and may have existed in restricted Cretaceous or Tertiary basins within Hudson Bay prior to glaciation. Siderite has been reported from Cretaceous sediment south of James Bay (Paré, 1982). In central Hudson Bay, an extensive unit overlying the Paleozoic succession

has tentatively been interpreted on seismic data as Cretaceous or younger sediment (A. Grant, pers. comm., 1988) and it is possible, therefore, that the mineral may be derived from Mesozoic sediments underlying Hudson Bay. Nevertheless, based on the evidence cited earlier, the Devonian interpretation is preferred.

Assuming a Paleozoic source within the bay, dispersal trends of siderite extend westward and southwestward toward the Manitoba coast, offshore from the outcrop area on the mainland near the mouth of the Nelson/Hayes River system, northward toward Coats and Southampton Island, and eastward in the area north of Cape Henrietta Maria. Less significant contributions of siderite from a Proterozoic source may be associated with westward or northward trends from the Belcher Island/Richmond Gulf area or Sutton Inlier, respectively.

4.5.3. Interpretation

Because of the similarity in provenance and distribution of certain lithologies and heavy mineral assemblages, the processes of sediment transport and deposition of both size fractions must be related. As outlined earlier, dispersal trends of the gravel fraction are interpreted to be glacially-derived. Similarly, certain heavy mineral assemblages appear to be extensions of glacial dispersal trains defined onshore south, southeast and west of the bay (Paré, 1982; Thorleifson, 1989).

Assemblage III (epidote-garnet-hematite) is interpreted as characteristic of sediments derived from Proterozoic rocks outcropping in the District of Keewatin and eastern Hudson Bay. In general, the regional distribution of this assemblage duplicates that of clasts from similar source areas. In the northwest quadrant of the bay, the gravel fraction can be related to the Proterozoic Dubawnt Group (Fig. 4.6). Sediment in the southeastern, southern and central areas of the bay appears to be derived from Proterozoic rocks of the Belcher Island Group outcropping along the southeast coast (Fig. 4.5).

Eastward dispersal of siderite (Assemblage V) (Fig. 4.12) from the Stopping River and Kwataboahegan Formations in the centre of the bay has also been recognized in the easterly transport of red carbonate erratics from an adjacent source area in central Hudson Bay (Fig. 4.4). Siderite dispersal extends to the Winisk Trough in the north and, in the south, beyond the Winisk Trough to the region of Henrietta Maria Arch and the Belcher Islands. Because the interpreted source of siderite is largely submerged, the mineral must be distributed by glacial processes of sediment transport and deposition.

If glacially-derived, siderite concentrations in seafloor sediment south of Southampton Island indicate sediment transport north or northwest from the outcrop area in central Hudson Bay. Northwestward transport in this area has also been suggested by the distribution pattern of greywacke/argillite and red/pink carbonate erratics. Alternatively, these siderite concentrations could indicate the presence of a Devonian outlier or another, yet unrecognized, siderite source on the seafloor.

Offshore dispersal in the south central part of the bay has been deduced previously from the distribution of igneous and metamorphic and, to a lesser extent carbonate and greywacke erratics. Because there is no evidence for northward glacial transport in any till sections exposed in the Hudson Bay Lowlands, these trends have been related to fluvial processes. Offshore trends are present in the distribution of siderite near the Nelson River (Fig. 4.12) and the orthopyroxene-epidote assemblage (Assemblage IV) near the Severn River (Fig. 4.8).

The relationship between siderite concentration, sediment texture and depth is illustrated in a profile extending seaward from the southern coast of Hudson Bay (Fig. 4.14). Nearshore, sandy diamictons have siderite concentrations exceeding 5% while, further offshore, siderite percentages in the finer grained sediments drop significantly.

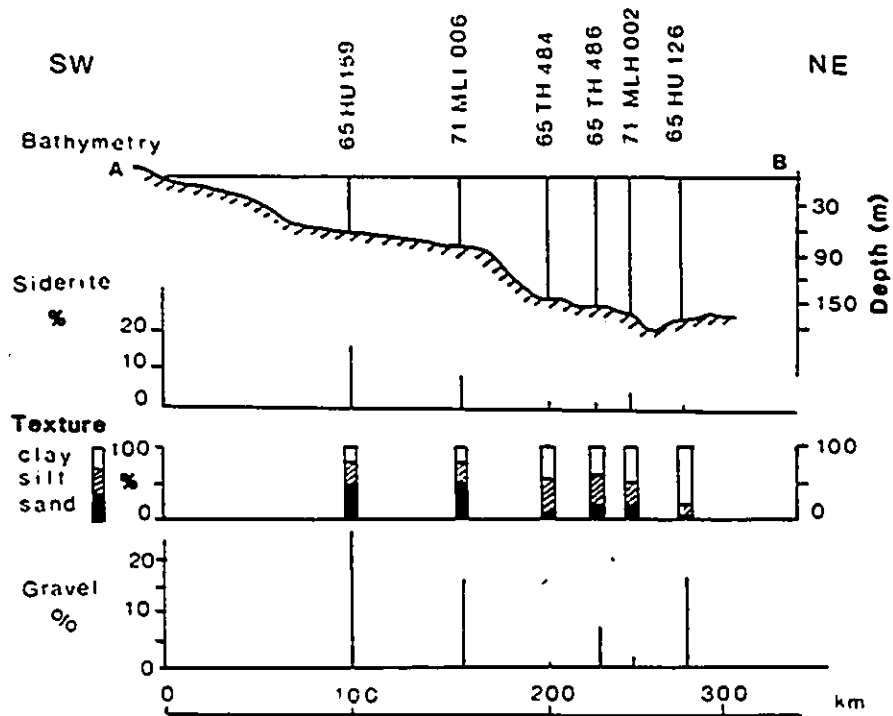


Figure 4.14: Offshore dispersal of siderite in relation to bathymetry and sediment texture. Location of profile shown in Figure 4.12.

The trend toward decreasing siderite values offshore may be related, at least in part, to sediment type. It is feasible that the seaward dispersal trends are a manifestation of post-glacial reworking of coastal exposures and/or previously deposited sediments by wave or tidal currents (Allen, 1979; McCave, 1985). In this case, the gravel fraction of fine-grained sediments must result from sea-ice rafting. Alternatively, the offshore trends could represent major flood events associated with (subglacial?) river systems draining into the bay. During deglaciation, increased offshore flow would occur due to the drainage of proglacial lakes to sea level. Great quantities of ice would be incorporated into the catastrophic flow and transported into the bay resulting in the deposition of glacial sediment directly, or indirectly from icebergs. The Hayes and adjacent river valleys have been interpreted as outlets of glacial Lake Agassiz during its final phase (Elson, 1967; Klassen, 1983; Dredge, 1983; Dredge et al, 1986) and offshore siderite trends in this area may record this drainage event.

4.6 MINERALOGICAL AND CHEMICAL ANALYSIS OF CLAY-SIZED FRACTION

The mineralogy and geochemistry of the clay-sized fraction (<0.002 mm) of the surficial sediments in Hudson Bay was analyzed to assess the relative influence of provenance, and oceanographic and diagenetic processes on sedimentation (Fig. 4.15). The clay-size fraction is composed of detrital material produced from the weathering and erosion of bedrock and transported by streams, marine currents, ice or the atmosphere. This terrigenous material is subsequently modified in the sea by diagenetic processes. The extent of this modification is dependent primarily on composition and sedimentation rate.

Clay-size material is chemically reactive due to its high surface area and the ability of certain minerals to adsorb mobile elements from seawater before or after deposition, particularly clay minerals (phyllosilicates) and iron and

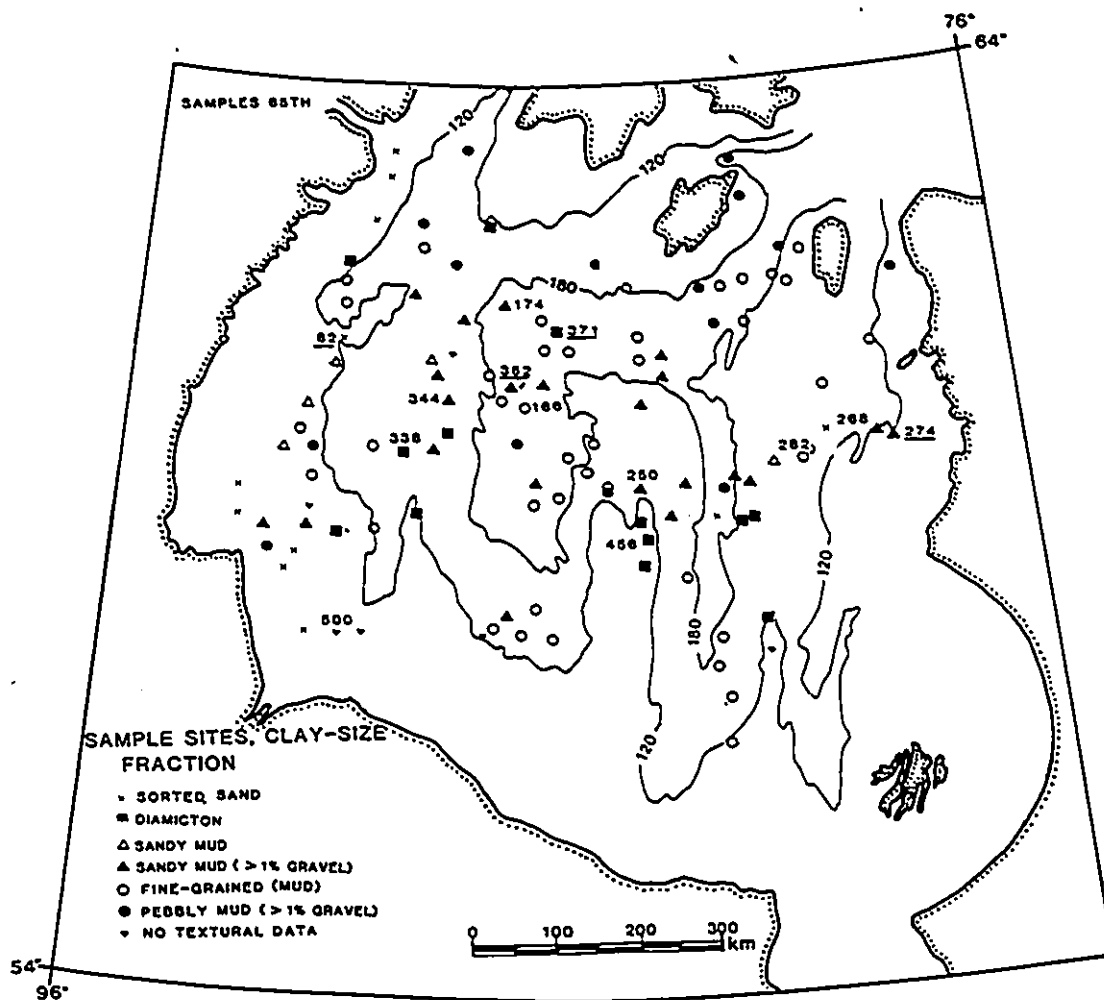


Figure 4.15: Sample distribution for analyses of clay-size fraction. Numbers refer to mineralogical analyses with illustrated x-ray diffraction patterns underlined (Fig. 4.16).

manganese oxides and hydroxides. Other minerals such as quartz and the ferromagnesian silicates are more stable. Post-depositional cation mobility induced by reduction in the sediment column results in precipitation of cations at/or near the sediment-seawater interface under oxidizing conditions. This process has been postulated as a mechanism for the formation of ferromanganese grain coatings (Speidel and Agnew, 1982).

4.6.1. Mineralogy

The mineralogy of the clay-size fraction of selected samples was determined from x-ray analysis and the results are summarized in Appendix H. The <0.002 mm fraction contains clay minerals and other fine mineral grains and/or organic matter in varying proportions. Although no rigorous attempt has been made to identify clay minerals or quantify results, certain distinctive minerals are recognizable (Fig. 4.16). The patterns exhibit an illite/muscovite (10 Å) and chlorite and/or kaolinite (7 Å) peak as well as reflections characteristic of quartz, feldspar and the carbonate minerals. Although rarely well developed, the expansion of a 15 Å peak on glycolation suggests that smectitic clays are present in sediments of the central and southern bay. Amphibole (8 Å), if present, tends to be associated with coarse sediment types from western and southern Hudson Bay, and the Midbay Bank.

The <0.002 mm fraction of samples offshore from the western and eastern shelf areas of the bay (65TH0082 and 65TH0274) (Fig. 4.16) lacks carbonate minerals. Offshore from the Keewatin coast, the illite/quartz peak (3.35 Å) predominates over chlorite/kaolinite and possible expandable mixed-layer clay reflections. Along the eastern coast (offshore from Cape Smith), the chlorite/kaolinite (7 Å) peak predominates and no indication of an expandable clay is present. Relative intensities of the reflections show a significant contribution from feldspar at this site compared to eastern and central Hudson Bay. Variations in mineralogy are presumably linked to differences in

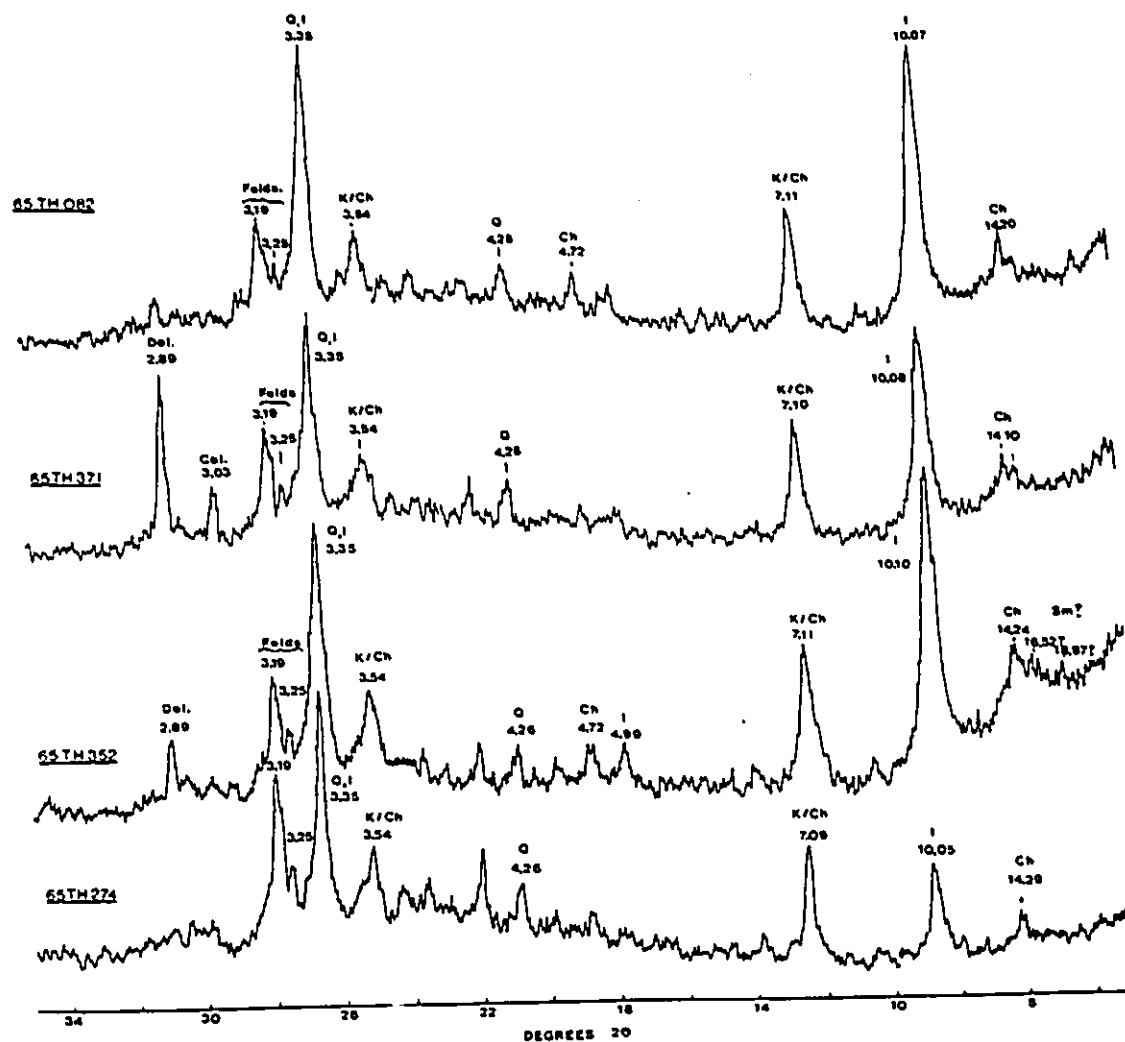


Figure 4.16: X-ray diffraction patterns of clay-sized fraction from selected samples. Symbols are as follows: Dol., dolomite; cal., calcite; Felds., Na and Ca feldspar; Q, quartz; I, illite; K, kaolinite; Ch, chlorite; and Sm, smectite.

source terrane. Chlorite is associated with mafic rocks which predominate in the Proterozoic terrane outcropping on the east coast of the bay.

Within central Hudson Basin (65TH0352 and 65TH0371), reflections from the clay minerals, particularly illite/muscovite (10 Å) and kaolinite/chlorite (7 Å) are well developed. Smectitic phases are also present, especially in the finer grained sediment (eg. 65TH0352) while dolomite, calcite, feldspar and quartz reflections are best developed in the diamicton (eg. 65 TH0371)(Fig. 4.16). In general, reflections from the carbonates, feldspars, quartz and ferromagnesian silicates, if present, are stronger in coarser sediment types throughout the bay, thus suggesting that they comprise a greater proportion of the clay-size fraction of coarse deposits.

Kaolinite and chlorite are difficult to distinguish by x-ray analysis because of overlap of the 7 Å and 3.5 Å reflections, so relative abundances can not be estimated. Significant amounts of kaolinite (>40%) were reported in central and eastern Hudson Bay (Bayliss et al, 1970). The percentage is much higher than generally observed in recent marine arctic sediments (Biscaye, 1965; Griffin et al, 1968) and has implications for both provenance and paleoclimatic studies. High (>20%) kaolinite percentages in the clay fraction of sediment from the Beaufort (Naidu et al, 1971) and Barents Sea (Bjorlykke et al, 1978) have been attributed to provenance, specifically the reworking of Mesozoic sedimentary rocks. With the exception of the kaolinite-cemented sandstone of the Thelon Formation, outcropping in the District of Keewatin, sources of kaolinite around Hudson Bay are limited to Cretaceous sediments of the Moose River Basin near James Bay. Cretaceous sediment within central Hudson Bay, if present, would provide a source within the bay. X-ray analysis of Paleozoic shale clasts from the centre of the bay, presumably Long Rapids Formation, also appear to contain minor kaolinite. It is possible, therefore,

that some clay minerals, particularly kaolinite and possibly smectite, were derived from local sources within the bay.

4.6.2. Geochemistry of Clay-sized Fraction

Geochemical data for the clay-size fraction (<0.002 mm) are summarized in Appendix G. The distribution of base metals can be related both to provenance and diagenetic processes (Speidel and Agnew, 1982). Base metal concentrations related to sediment source are localized in specific areas offshore from or overlying distinctive geological terranes and tend to be associated with coarse sediment types. Diagenetic reactions, on the other hand, are largely a function of the physical-chemical conditions on the seafloor and are controlled by the rate of sedimentation and the supply of reacting material, including organic matter, in an oxidizing environment (Calvert and Price, 1977). Ferromanganese deposits resulting from marine diagenesis are widely distributed in shallow northern seas at depths ranging from 15 to 270 m in varying sediment types including muds, sands and pebbly sands (Winterhalter, 1966; Calvert and Price, 1977). However, the process is much more important in muddy sediments due to the high porosity, reduced sedimentation rate and predominance of clay minerals (Winterhalter, 1966).

In Hudson Bay, strong similarities are present in the distribution of cobalt, nickel, manganese, and to a lesser extent, iron and zinc. These elements are commonly associated with secondary enrichment processes in both lacustrine and shallow marine environments (Levinson, 1974).

Cobalt: Cobalt abundances in Hudson Bay clay-size fractions range from 53-13 ppm. The average value (26 ppm) is comparable to average values of cobalt in the clay fraction of tills from the Baker Lake region, District of Keewatin (Schau, 1983). High values (>30 ppm) predominate in the centre of the bay (Fig. 4.17). Values are slightly elevated above onshore background levels in two areas: (1) offshore from the Keewatin coast near Rankin Inlet, and (2) east of Cape Churchill.

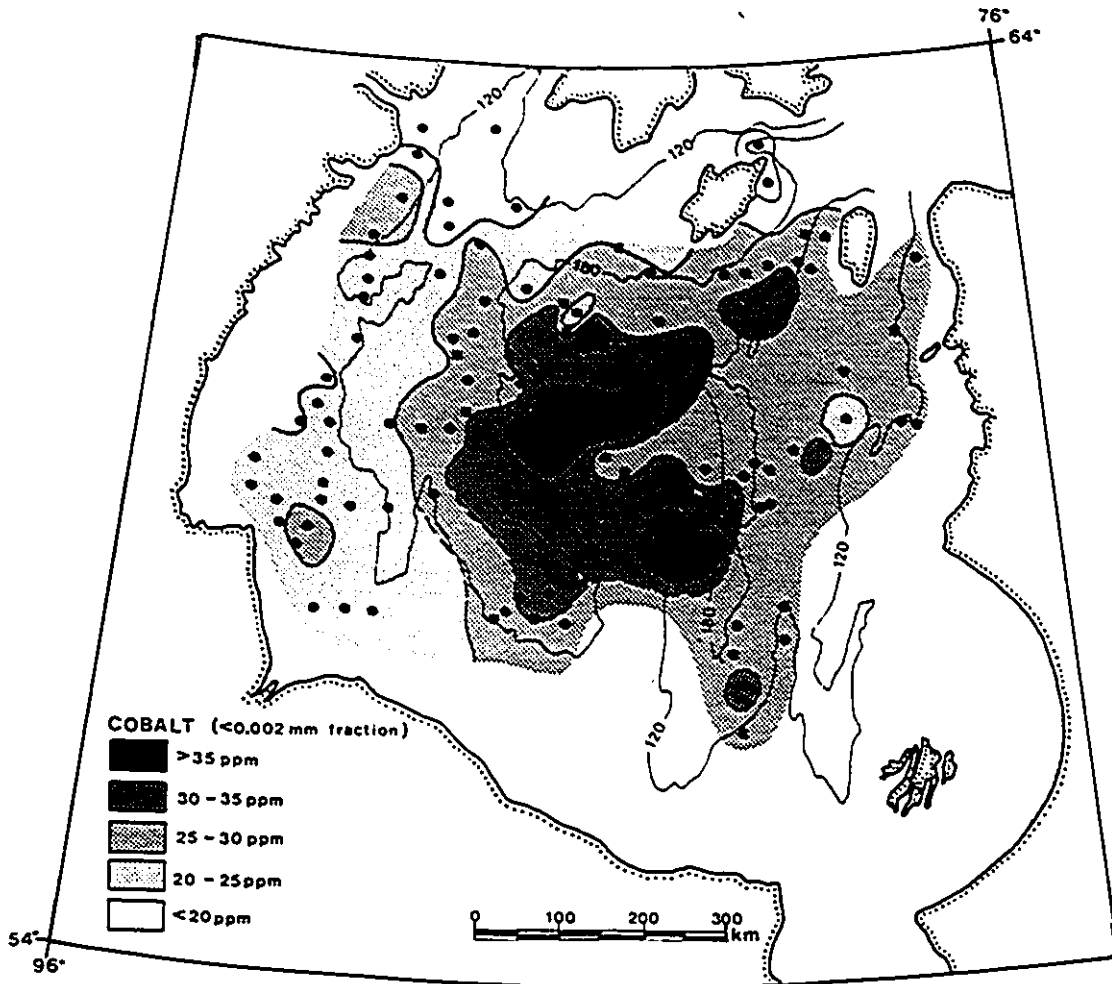


Figure 4.17: Cobalt distribution in clay-size fraction.

Nickel: Nickel values range from 51 to 107 ppm and average 71 ppm. The distribution (Fig. 4.18) is similar to cobalt with highest values (>80 ppm) occurring in the centre of the bay, and east of Cape Churchill. High percentages are also present in the southern bay. Nickel values along the western coast of the bay are comparable to those reported from the clay fraction of till sampled along the Polar Gas pipeline route (Shilts, 1980b). Nickel enrichment occurs offshore from the Keewatin coast south of Chesterfield Inlet (one value exceeds 91 ppm) and onshore between Rankin and Chesterfield Inlet where nickel values in tills range from 100-→150 ppm (Shilts, 1980b; Rencz and Shilts, 1980).

Manganese: The range in manganese concentration varies from 1.00 to 0.04 percent (Fig. 4.19). Values from western Hudson Bay are similar to those reported from the clay fraction of tills from western and southwestern coastal areas (Schau, 1983; Shilts, 1980b). Highest values (>0.20%, 2000 ppm) are restricted to the centre of the bay in areas with high cobalt and nickel values.

In general, higher percentages of cobalt, nickel and manganese are concentrated in the central part of the bay where the sedimentation rate is low. Concentrations are not totally dependent on depth or sediment type although there is some tendency toward increasing values with depth, particularly in muddy sediments (Fig. 4.20) for all these elements. With respect to cobalt, this relationship is fairly consistent for all sediment types with the exception of diamictons overlying the Midbay Bank (Fig. 4.20a). Nickel results are more poorly defined (Fig. 4.20b). Within sands and diamictons, nickel concentrations show an inverse association with depth, with higher values present in shallower parts of the bay. The coincidence of nickel enrichment in the sediments along the western coast of the bay with tills from onshore areas in the District of Keewatin (Rencz and Shilts, 1980) suggests a direct

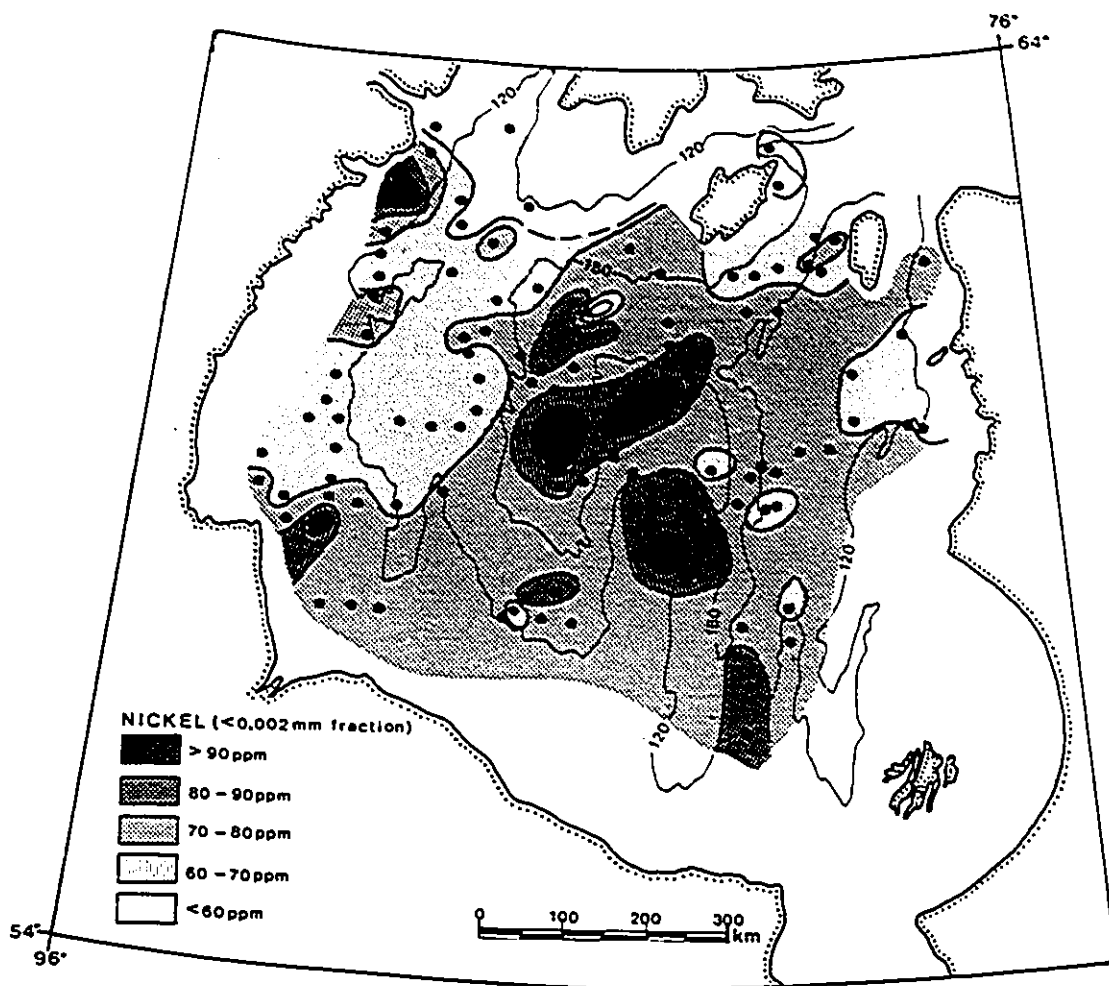


Figure 4.18: Nickel distribution in clay-size fraction.

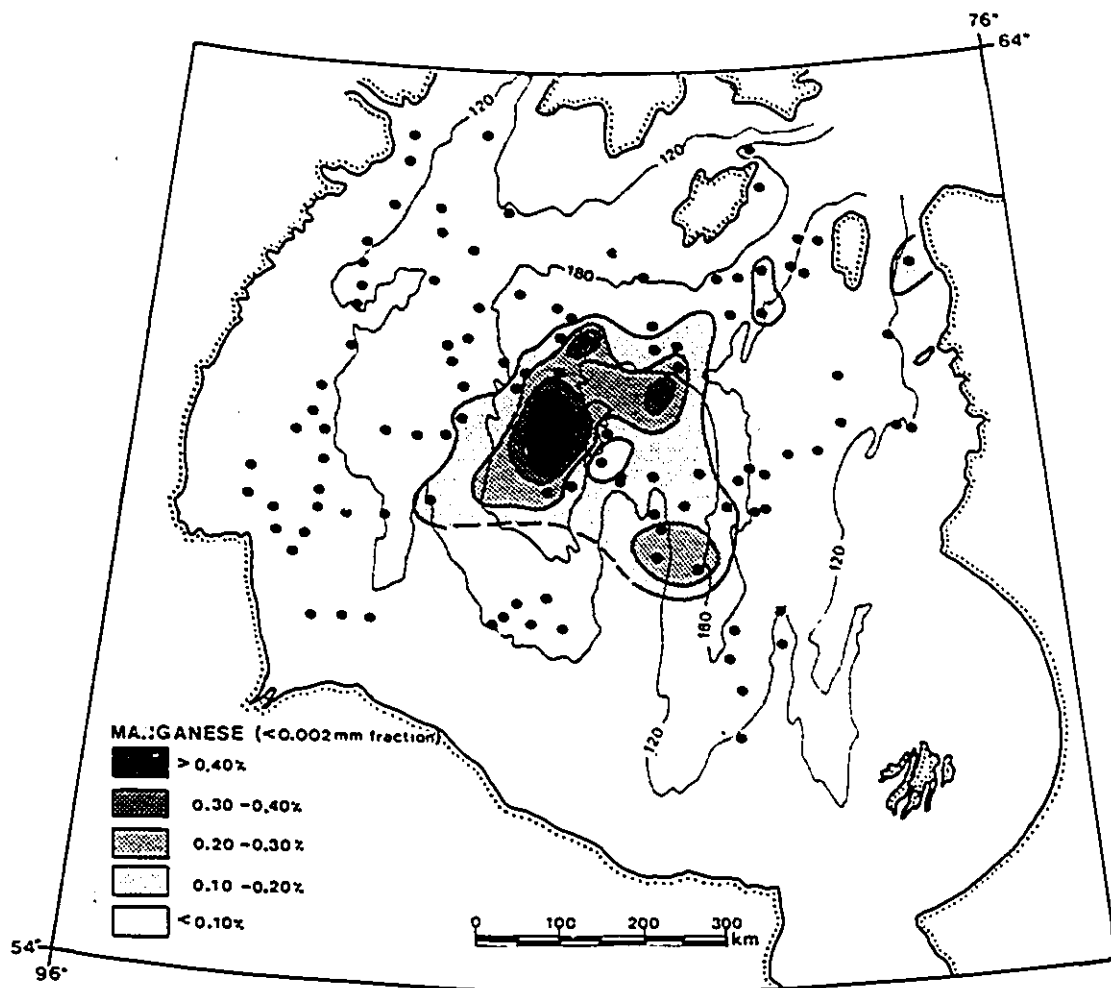


Figure 4.19: Manganese distribution in clay-size fraction.

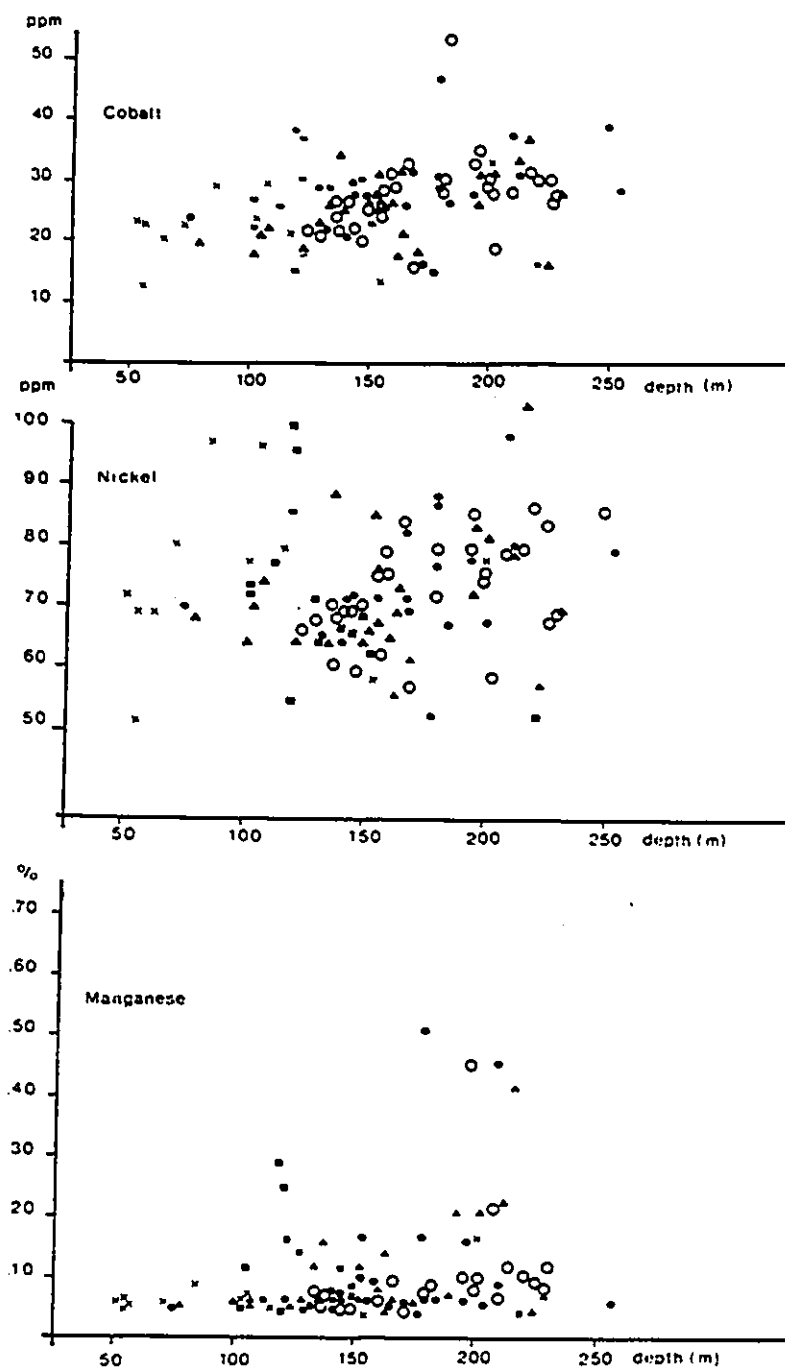


Figure 4.20: Relationship between Co, Ni, and Mn concentration, sediment type and depth. Symbols for the sediment types are defined in Figure 4.15. Concentrations within muddy sediments (o) show a tendency to increase with depth.

relationship to the onshore source. In general, manganese values in all sediment types increase with depth (Fig. 4.20c). In shallow parts of the bay concentrations are consistently low with the exception of diamictons overlying the Midbay Bank. In deeper areas, manganese values vary ranging from low to anomalously high.

Iron: Iron concentrations vary from 2.7-7.5% and average 4.8%, a value similar to the background levels recorded along the proposed Polar Gas pipeline route in the District of Keewatin (Shilts, 1980b). Highest values (>5.5%) occur in parts of the Hudson Basin and adjacent areas, north of the Midbay Bank including the Winisk Trough, offshore from Cape Churchill, and offshore from the Keewatin coast between Chesterfield and Rankin Inlet (Fig. 4.21).

Zinc: Although zinc values in the bay range from 109-227 ppm, the average 157 ppm is similar to the west coast regional value of approximately 150 ppm in marine clayey silt (Shilts, 1980b). Concentrations in southeastern and central Hudson Bay are elevated above these background values with areas of enrichment (>180 ppm) focused in the sediments of the Hudson Basin, west of the Midbay Bank including the Winisk Trough, and in a tongue extending eastward from the mouth of the Churchill River (Fig. 4.22).

High concentrations of iron and zinc are present in the central area of Hudson Bay, as well as marginal regions, and the general trend toward increasing concentrations with depth, recognized in muddy sediments, is not evident within coarser material (Fig. 4.23). The distributions possibly reflect the combined effects of diagenesis and provenance, with concentrations in the fine-grained sediments related more to sedimentological and/or diagenetic factors. Iron and zinc concentrations in sands and diamictons are variable, suggesting that the distribution is a function of the sediment composition and is dependent on the source. Although iron is associated with

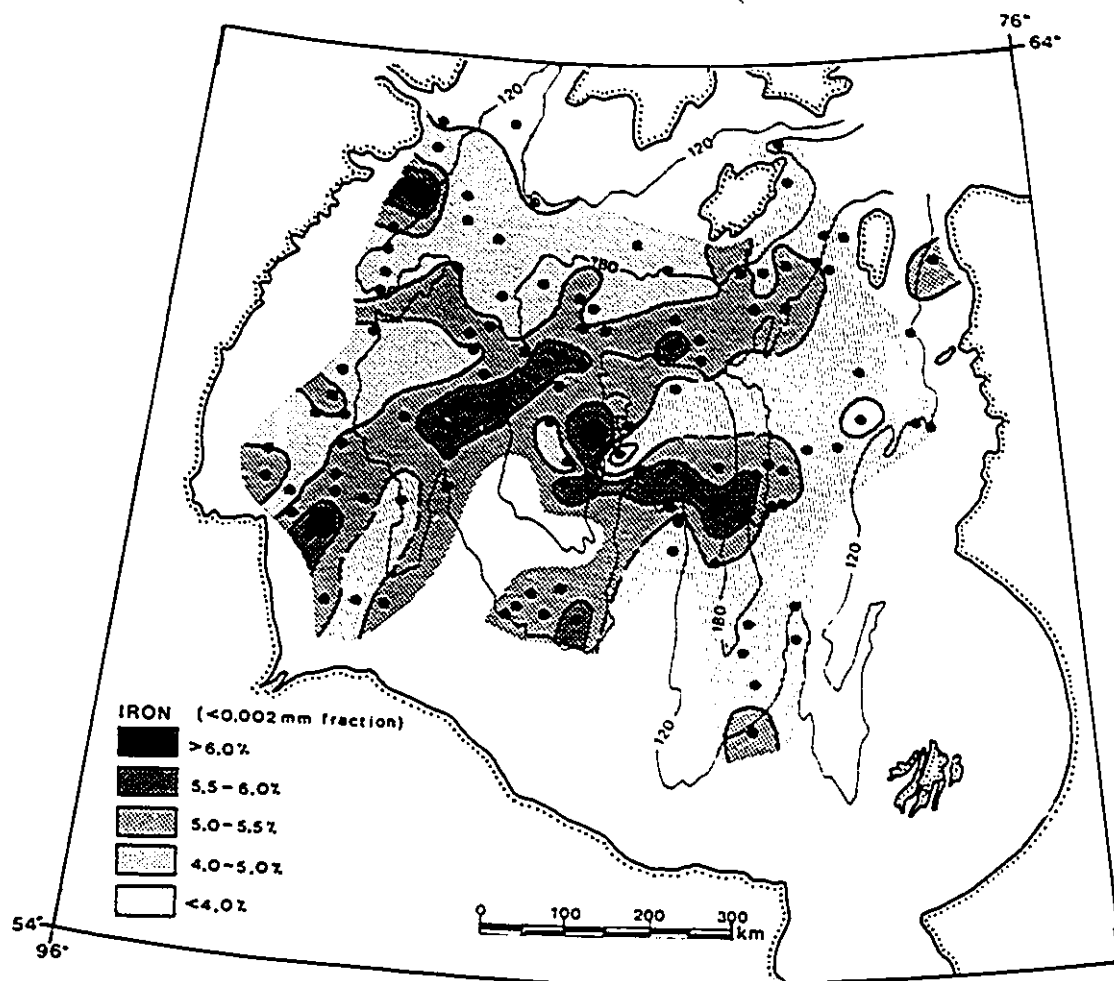


Figure 4.21: Iron distribution in clay-size fraction.

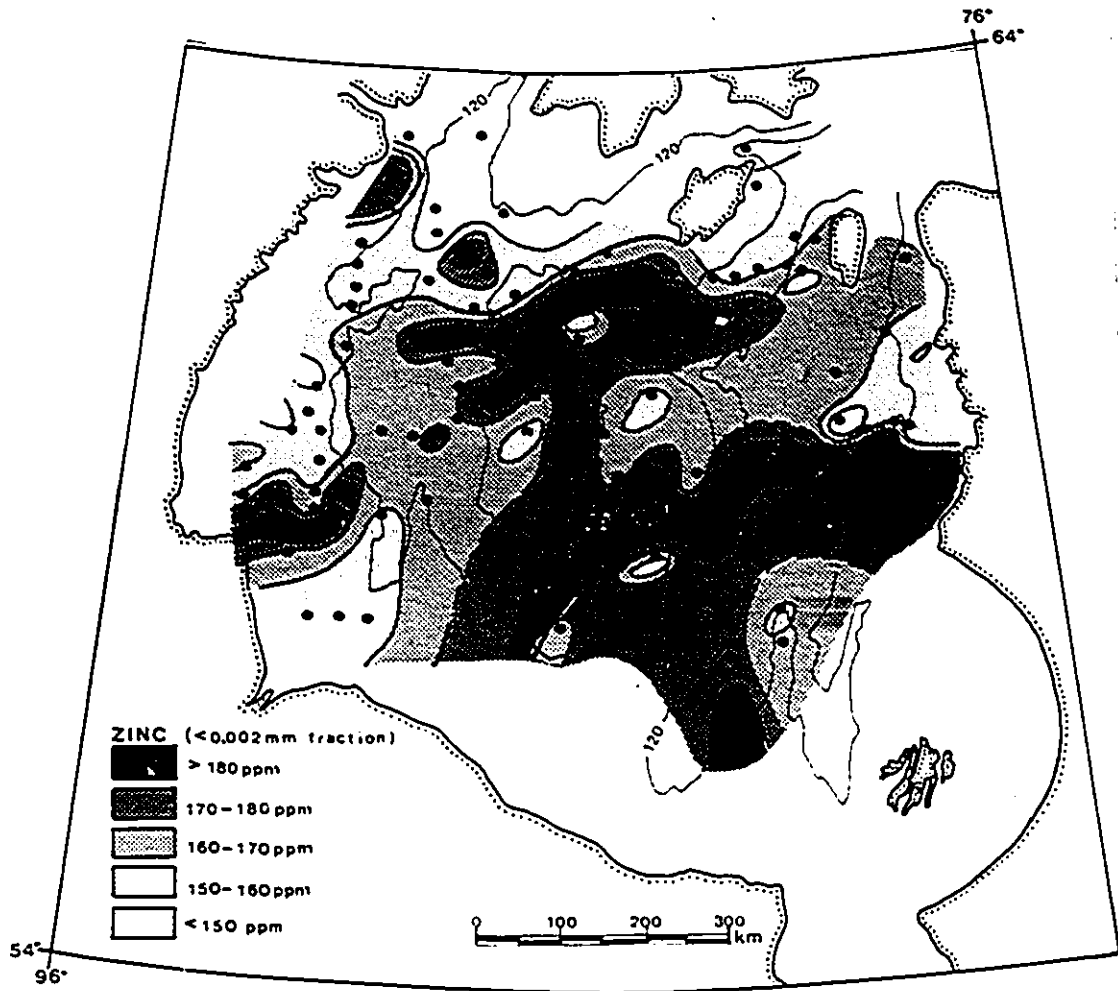


Figure 4.22: Zinc distribution in clay-size fraction.

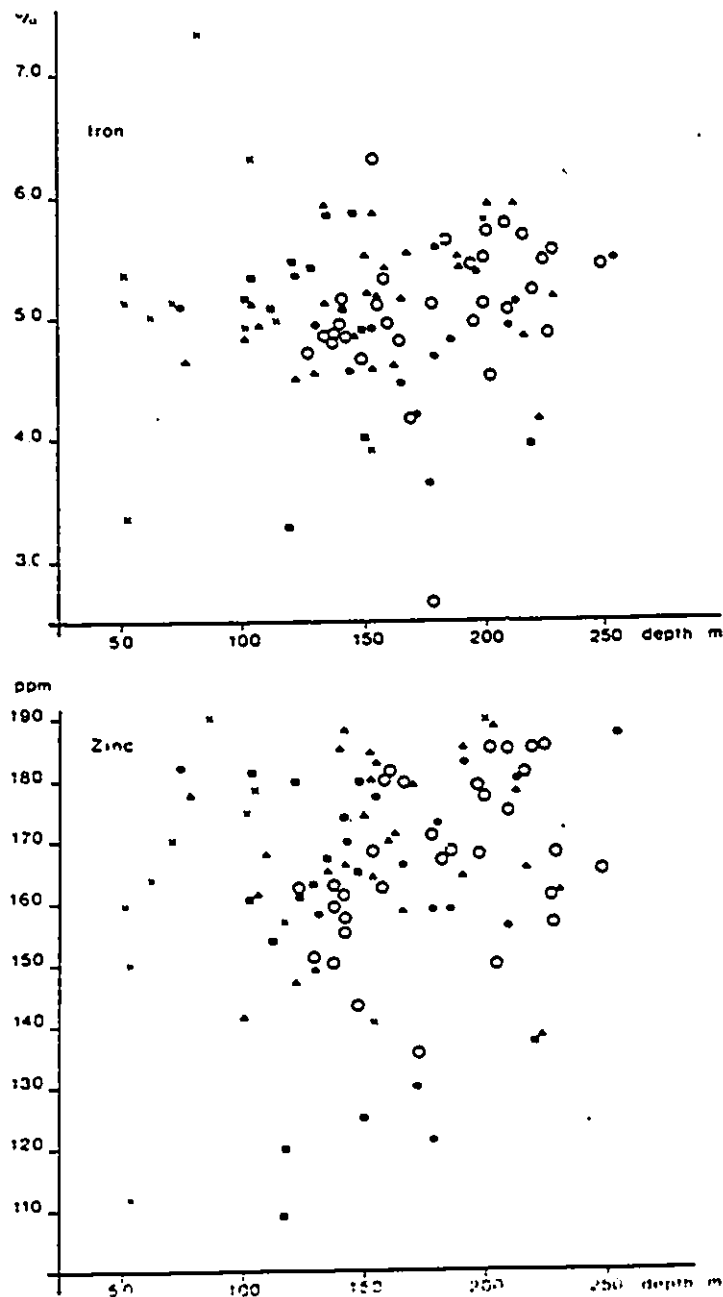


Figure 4.23: Relationship between Fe and Zn concentration, depth and sediment type. For symbols see Figure 4.15.

manganese in the formation of secondary ferromanganese stains and coatings on the seafloor, it also occurs in mineral phases that are geochemically separate from manganese, such as magnetite, hematite and ferromagnesian minerals (Poppe et al, 1984).

Copper: The distribution of copper in the clay-size fraction differs from those elements previously discussed (Fig. 4.24). Concentrations are variable and trends are not recognized within any sediment type (Fig. 4.25). Copper abundances in Hudson Bay range from 22-170 ppm, with values averaging 40 ppm. High concentrations (>40 ppm) tend to occur in shallower water (Fig. 4.25) with values exceeding 90 ppm present off the mouth of the Churchill River, in western Hudson Bay and in the fine-grained sediments of Hudson Basin. Background concentrations from the clay fractions of tills sampled along the Polar Gas pipeline route (Shilts, 1980b) and, in more detail, the District of Keewatin (W. Shilts, pers. comm., 1988) are in the 40-50ppm range, similar to the bay. Within the District of Keewatin, copper anomalies of 100-300 ppm are present between Rankin Inlet and Chesterfield Inlet and in an area north of Eskimo Point. Although copper values offshore from these two areas are lower than those reported from the tills, the coincidence of the anomalies suggests that copper distribution in these areas is related to sediment transport offshore from the District of Keewatin.

Chromium: Chromium values range from 247-99 ppm with significant fluctuations between adjacent values, particularly in the centre of the bay (Fig. 4.26). The average value (146 ppm) is higher than regional values reported from tills (<100 ppm) or marine clayey silts (120 ppm) sampled along the western coast of Hudson Bay (Shilts, 1980b). On the regional scale, high values (>160 ppm) are present in sediments of the southern and southwestern bay, and in localized areas offshore from the Keewatin coast. Lower chromium concentrations are present in the eastern, northwestern and central bay. In central Hudson

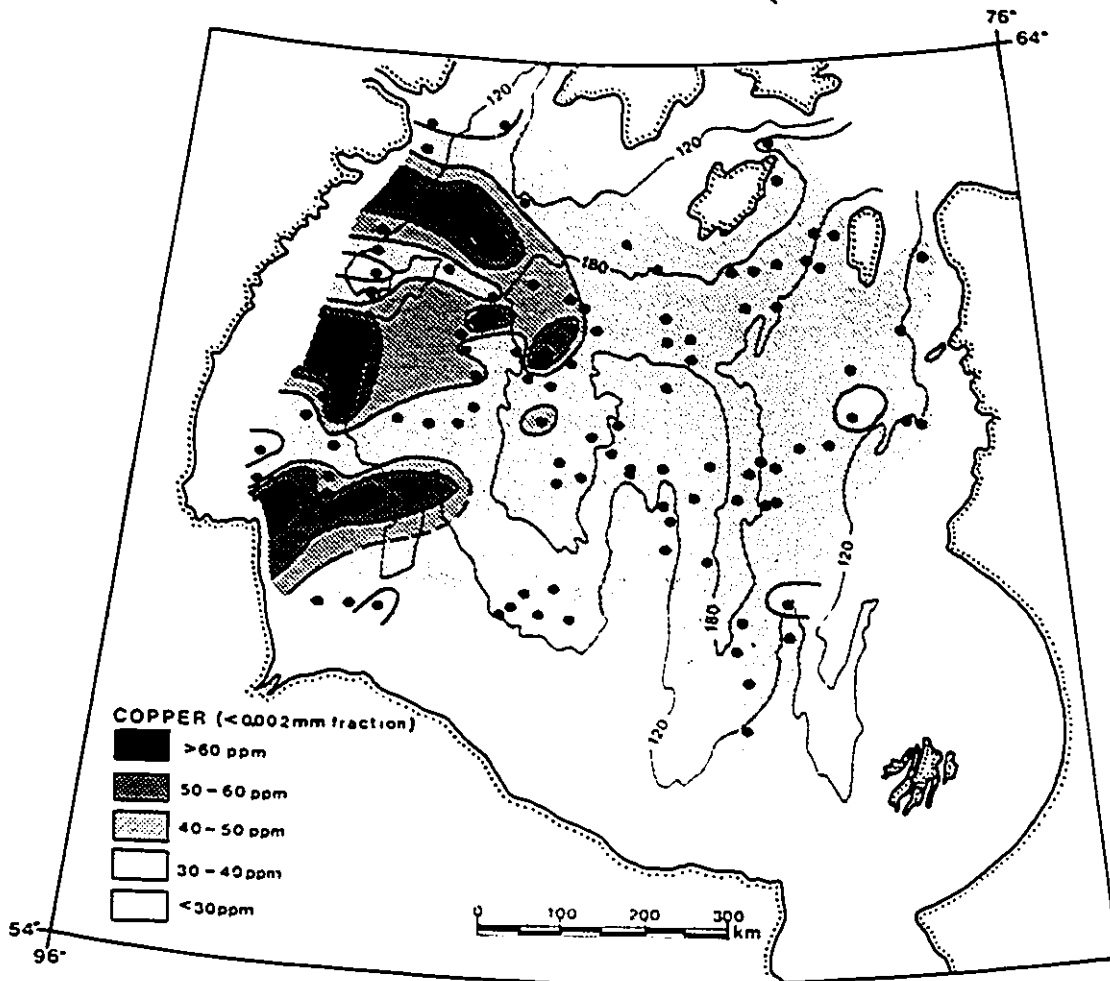


Figure 4.24: Copper distribution in clay-size fraction.

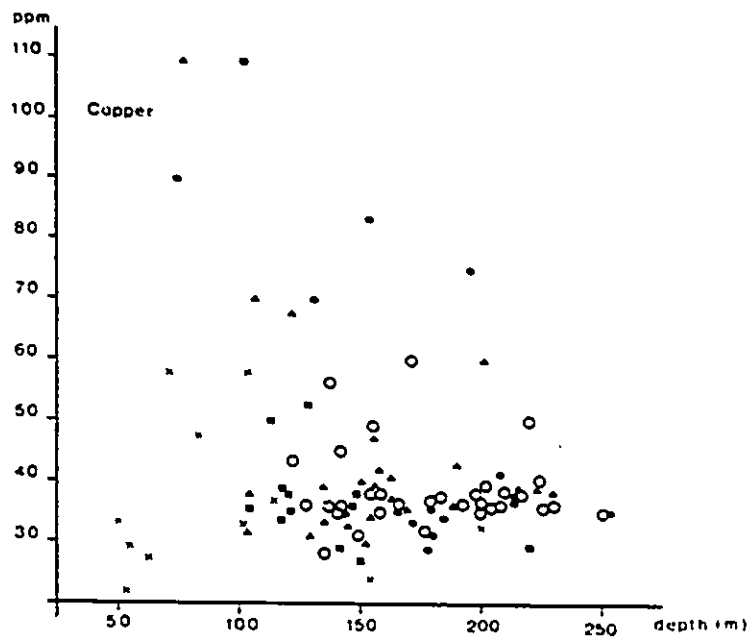


Figure 4.25: Relationship between Cu concentration, depth and sediment type. For symbols see Figure 4.15. No obvious relationship exists among variables.

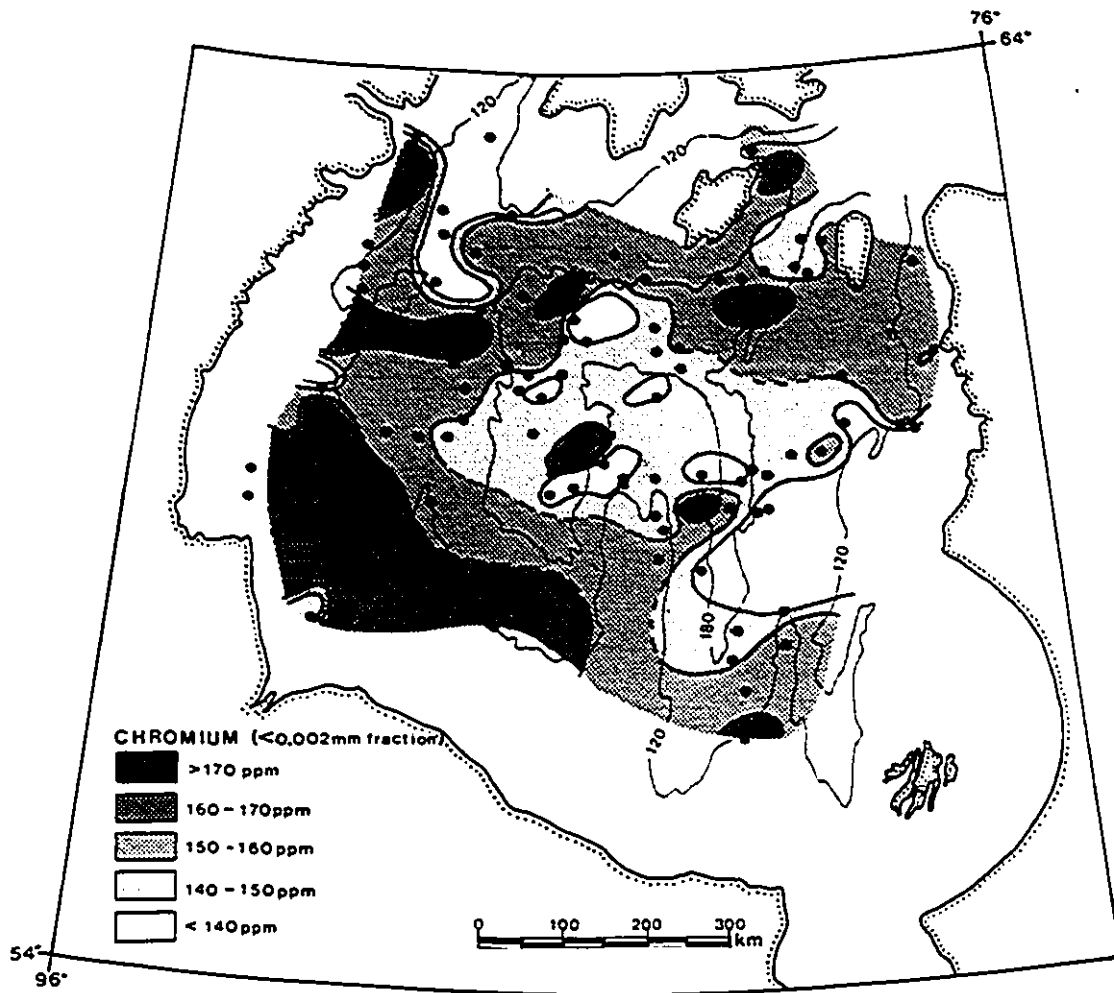


Figure 4.26: Chromium distribution in clay-size fraction.

Bay, the distribution is the inverse of other elements, particularly cobalt, nickel and manganese. Chromium values tend to decrease with depth particularly in association with the fine grained sediment types (Fig. 4.27a).

Lead: With few exceptions, variations in lead concentrations are low and no obvious relationship is present with sediment type (Fig. 4.27b). Lead in the clay-size fraction averages 43 ppm, ranging from 27-137 ppm. Concentrations are highest in southern and southwestern Hudson Bay and fairly low in the central region with the exception of several isolated sites (Fig. 4.28). The maximum value (137 ppm) is present north of Midbay Bank. Within the bay, lead values are higher than the regional Keewatin values of 20-30 ppm.

4.6.3. Interpretation of Base Metal Distribution

Based on the distribution and abundance of base metals within the surficial deposits in Hudson Bay, certain areas are characterized by similar mineralogical and geochemical associations.

Central Bay

Sediments of central Hudson Bay, particularly the Hudson Basin and east of the Midbay Bank, are enriched in Mn, Co and Ni and associated with elevated values of Fe, Zn, Cu and Pb at isolated sites. This assemblage is characteristic of sediments subjected to secondary enrichment processes (Speidel and Agnew, 1982; Levinson, 1974) and it is probable that trace element concentrations in the central bay result from these processes. Diagenesis occurs throughout the shallow marine environment depending on the physico-chemical conditions of the seafloor. The effects appear most pronounced in areas with low rates of sedimentation and organic content providing the composition of the sediments can supply the relevant cations (Calvert and Price, 1977). The localization of the Mn, Co, Ni anomaly in central Hudson Bay implies that the conditions in central Hudson Bay support diagenetic reactions.

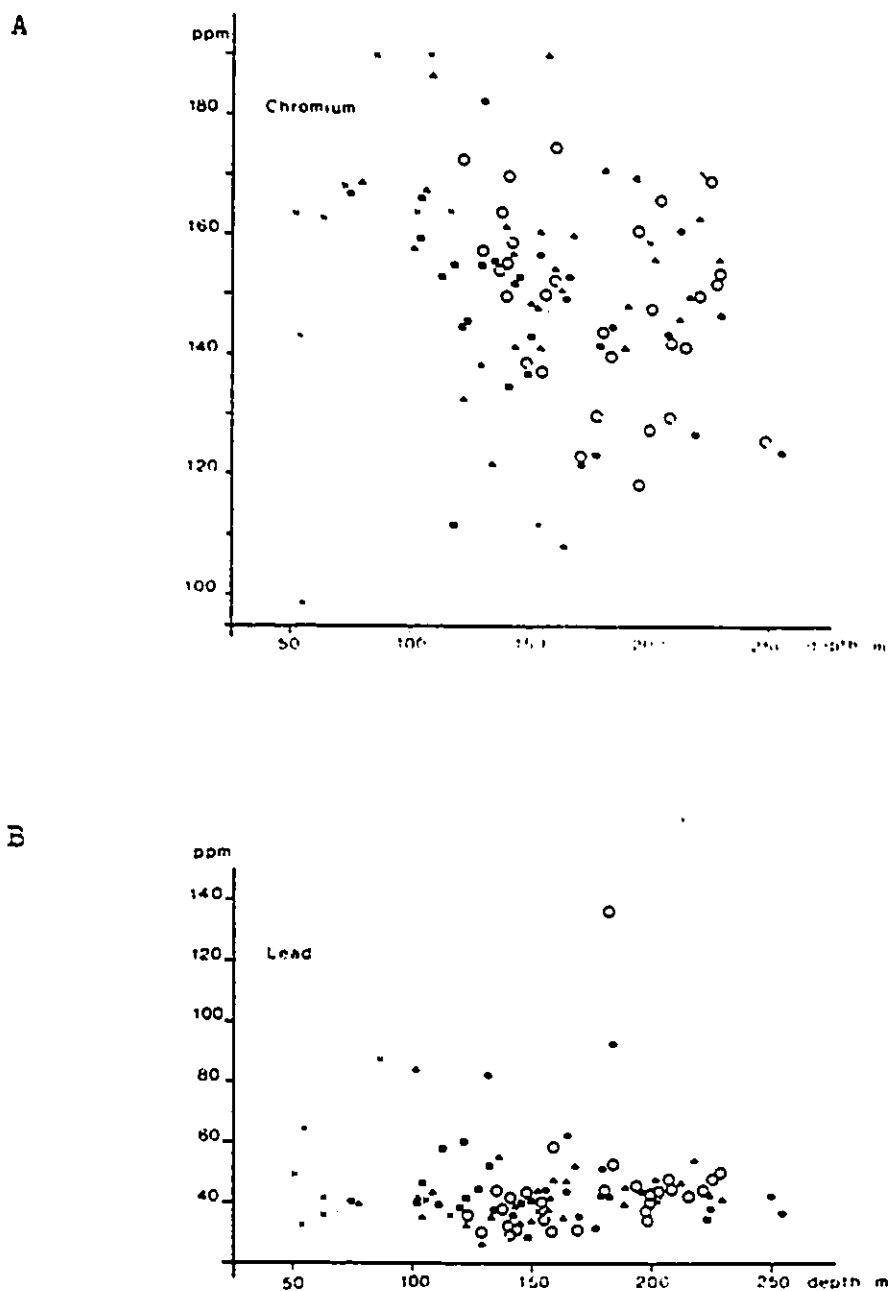


Figure 4.27: Relationship between Cr and Pb concentration, depth and sediment type. Symbols defined in Figure 4.15. Chromium concentrations show a general decrease with depth.

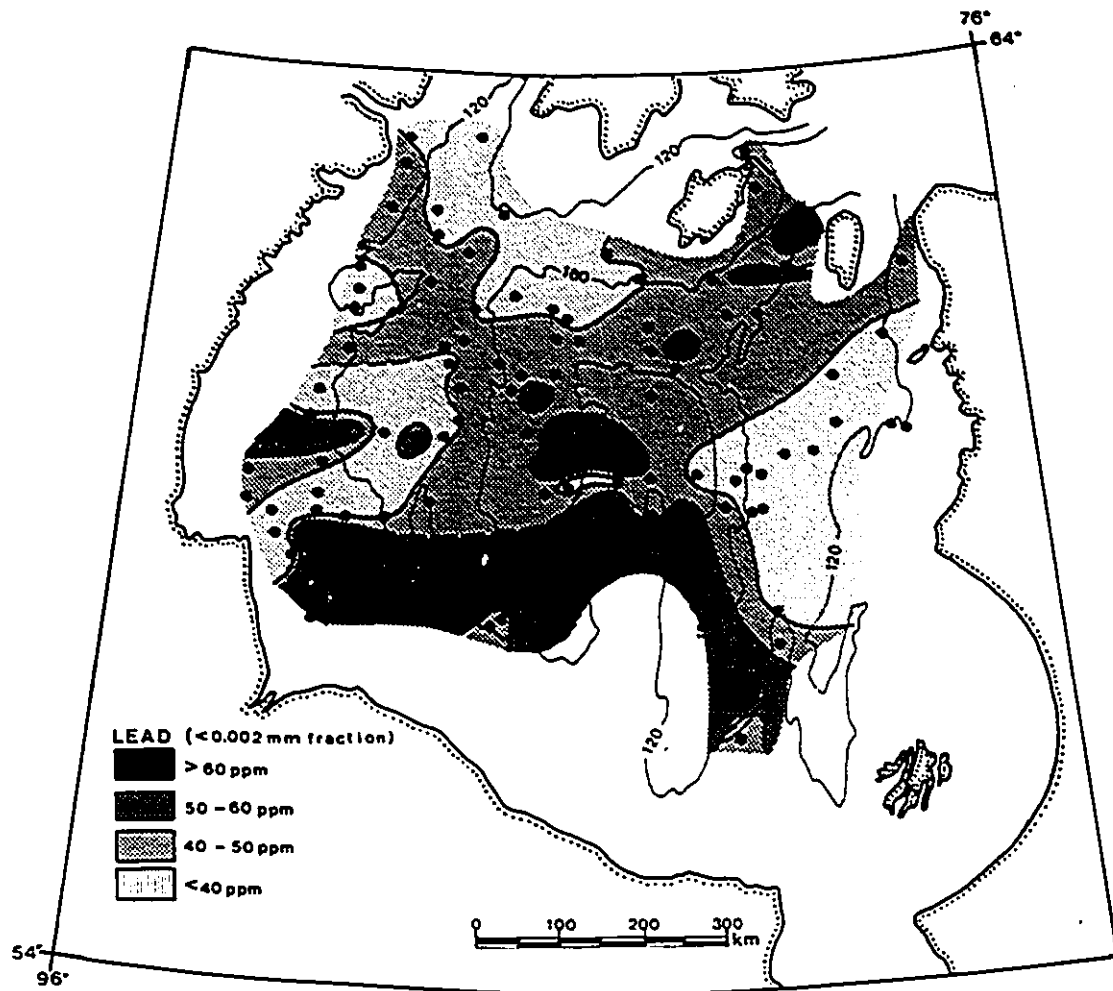


Figure 4.28: Lead distribution in clay-size fraction.

Several characteristics of the surficial sediment of this central area distinguish it from deposits elsewhere in the bay. One of the most striking is sediment colour. The seafloor sediments are characterized by a 5 cm thick reddish-brown veneer (Leslie, 1963; Pelletier et al, 1968) as opposed to the olive grey to green material covering the rest of the seafloor. Leslie (1963) attributed the colour to the oxidation of fine sediment in the water column during settling. However, these sediments are also characterized by a low organic content (Pelletier, 1969) which suggests minimal seafloor reduction by organisms. Higher abundances of smectic clays in central Hudson Bay also implies a greater ion exchange capacity in these deposits. It is possible, therefore, that the colour and geochemistry of the sediments indicate a unique physio-chemical environment related to a distinctive source or sources within the bay.

Keewatin coastal zone

High values of Ni, Cu, Fe, Zn and Cr in the clay-size fraction of coarse sediment directly offshore from Rankin Inlet correspond to anomalies recognized onshore from regional till geochemical studies (Shilts, 1980b; Schau, 1983). The correlation between the offshore-onshore signature, particularly with respect to copper, suggests offshore sediment transport. The anomalies are not related spatially to the present river systems entering the bay in the area. Eastward sediment dispersal from the District of Keewatin (interpreted from the distribution of Dubawnt clasts (Fig. 4.6) and hematite in the heavy mineral fraction (Fig. 4.8)) has been related to glacial processes.

Southern shelf zone

The region is characterized by high values of Fe, Pb, Cu, Zn, and Ni that form a pattern extending northeastward from the mouth of the Churchill, Knife and Seal Rivers. The anomaly is associated with sorted sands and appears to be related to fluvial sedimentation, although the source of the high trace element concentrations is not clear. Possible anomalies are

present in shield terranes of northern Manitoba, particularly along the Seal River (Schledewitz, 1986).

The clay geochemistry in the remainder of southern Hudson Bay is variable. High concentrations of Pb and Ni are present across the region, with Fe and Cr values elevated in the southwest and Zn in the southeast. Both gravel lithologies and heavy mineral assemblages from across the area indicate that the sediment is derived primarily from a Proterozoic source in southeastern Hudson Bay and the results of the geochemical analyses of the clay fractions are generally compatible with this interpretation. South of the bay, high base metal concentrations are associated with tills derived from this Proterozoic terrane (Thorleifson, pers. comm., 1988).

Quebec coastal zone

Sample density east of the Winisk Trough is low. Concentrations of Co, Ni, and Zn are generally higher off the eastern than the western coast of Hudson Bay, and Cu concentrations are low across the region. Elevated Cr values are present offshore from the Proterozoic rocks of Cape Smith and, together with Pb, the Belcher Islands. The relative enrichment of Cr offshore from a source in the mafic and ultramafic rocks of the Cape Smith and Belcher Island Fold Belts, suggests westward sediment transport from Nouveau Quebec.

Northern Hudson Bay

Trace element concentrations of all elements in northern Hudson Bay are low. The results may be a function of a high percentage of carbonate minerals in the clay fraction compared to other areas of the bay (Fig. 4.15). The area is also characterized by high proportions of Paleozoic limestone clasts in the fine gravel fraction.

4.7. CARBONATE CONTENT OF SURFICIAL SEDIMENT (Silt plus Clay Fraction (<0.063 mm))

4.7.1. Carbonate Distribution

The distribution of carbonate in the silt and clay fraction (<0.063 mm) (Appendix I) of the surficial sediment is shown in Fig. 4.29. It is similar to the distribution of grey carbonate clasts (Fig. 4.3). Percentages are high in northern Hudson Bay south of Southampton Island and the Midbay Bank and fall off markedly toward the east and west coast within the limits of the Paleozoic outcrop area. In southern Hudson Bay, sites offshore from the major rivers indicate slightly elevated values in association with coarser sediment types. With the exception of these sites and northern Hudson Bay, carbonate values are low in coastal areas where biologic activity is most likely. This suggests that biogenic material forms an insignificant portion of the carbonate in the silt and clay fraction and the bulk of the material is derived from bedrock sources.

Studies of carbonate comminution processes in glacially derived sediments indicate that calcite and dolomite predominate in the silt-size fraction (Dreimanis and Vagners, 1969). However, x-ray analysis (Fig. 4.16) of sediment from various sites, particularly those in northern Hudson Basin, confirms the presence of carbonate minerals in the clay-size fraction as well. An indication of the regional distribution may be inferred from calcium distribution in the clay-size fraction (Fig. 4.30). The relative abundance and distribution of calcium (<0.002 mm), calcium carbonate (<0.063 mm) (Fig. 4.29), and Paleozoic limestone (2-5.6 mm) (Fig. 4.4) all coincide, and provide evidence of the relative importance of sediment derived from Paleozoic carbonate sources outcropping beneath and adjacent to Hudson Bay. Variations in the abundance of carbonate in the surficial deposits are essentially an index of the degree of sediment mixing with material derived from sources outside the bay.

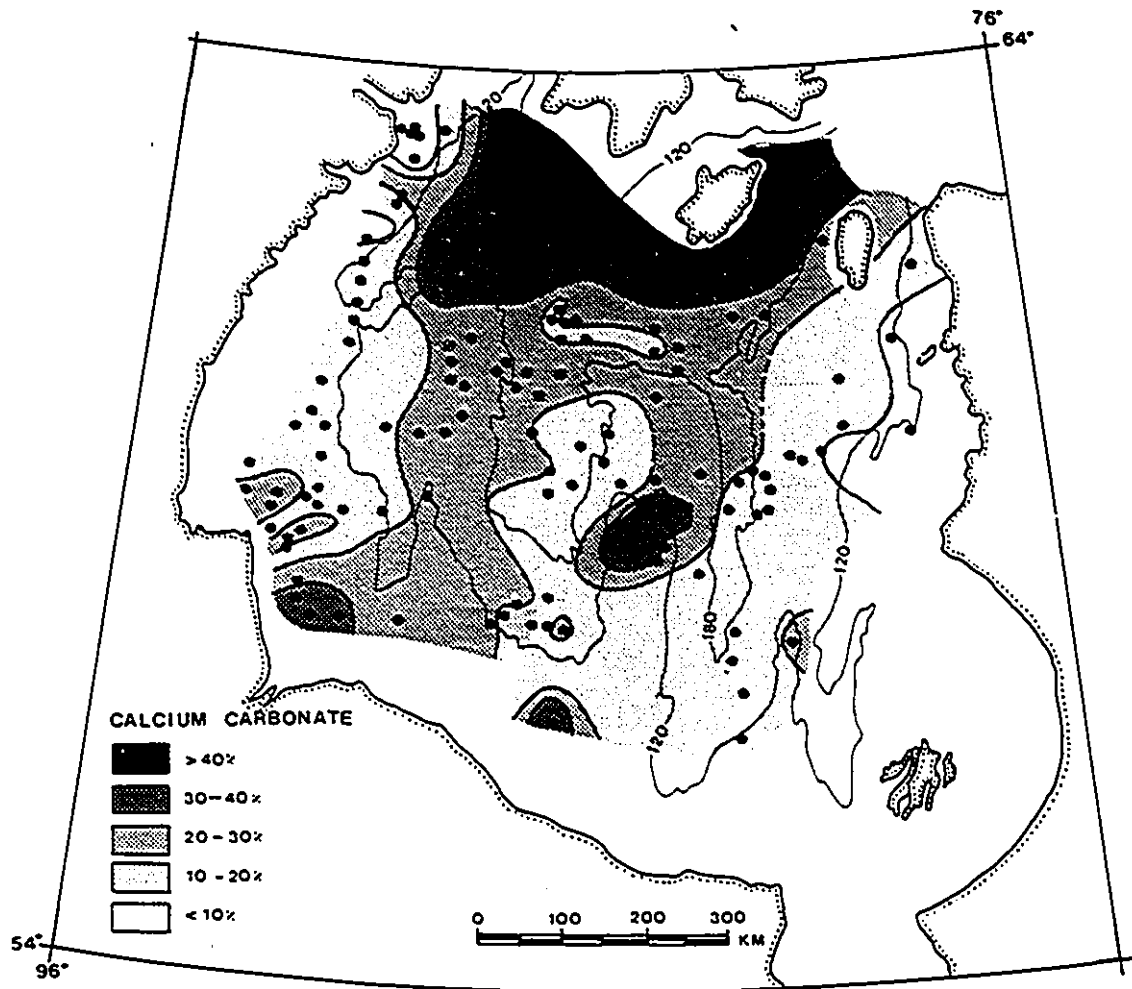


Figure 4.29: Distribution of calcium carbonate (<0.063mm). Values represent percentage calcium carbonate equivalent as calculated from analysis by the Leco Carbon Determinator.

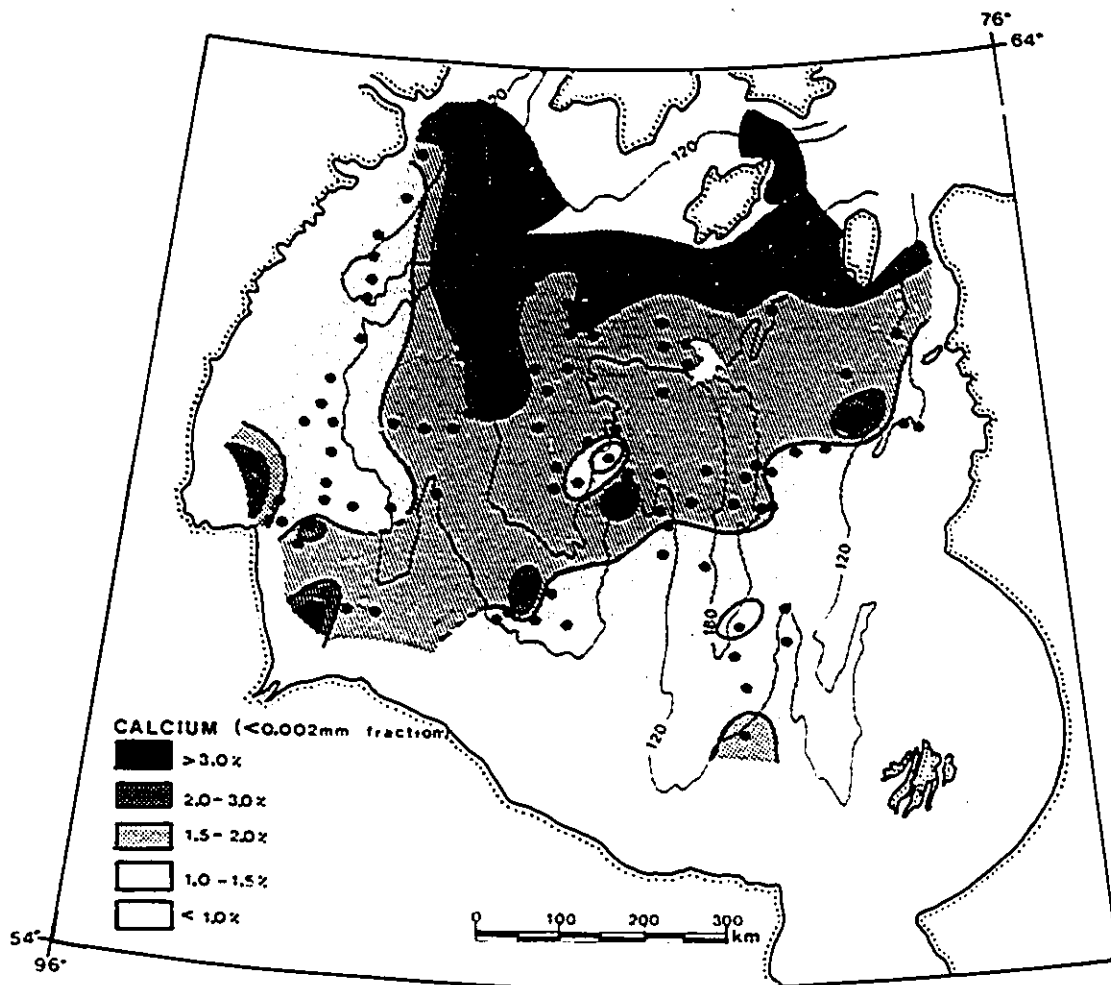


Figure 4.30: Calcium distribution in clay-size fraction.

4.7.2. Interpretation

Surficial sediments of northern Hudson Bay characteristically have high carbonate concentrations in all size fractions which indicates little sediment input from the Precambrian terrane. The area is underlain by Paleozoic carbonate formations which also outcrop on parts of Southampton and Coats Island (Fig. 1.5). The dispersal of carbonate (Fig. 4.29) indicates either lack of sediment input from other sources, southward and westward transport of Paleozoic carbonates in northern Hudson Bay from the Foxe Basin region, or eastward transport of sediment with a decreasing input of material derived from Precambrian rocks outcropping in the District of Keewatin. Eastward transport of sediment by glacial processes in this region has been proposed on the basis of the dispersal of grey carbonate and Dubawnt clasts and is supported by ice flow indicators (striations and glacial flutes) present on southwestern Southampton Island and on Coats Island.

Other areas of relatively high carbonate concentrations include Midbay Bank and southern Hudson Bay, offshore from the mouths of the major river systems. Paleozoic carbonates of the red Williams Island Formation underlie the Midbay Bank and the fine gravel fraction of the surficial sediment from this area is dominated by these lithologies. Carbonate contents determined in the <0.063 mm fraction are associated with sandy muds and diamictons and also derived, most likely, from the local source.

Carbonate concentrations in southern Hudson Bay (<0.063 mm fraction) , on the other hand, are associated primarily with sorted sands. These sediments may represent the bedload of rivers flowing into the bay. The rivers transport material eroded from bedrock and Quaternary deposits exposed along their channels (Adshead, 1983) which are high in carbonate debris incorporated by glaciers flowing across the Paleozoic terrane in the bay (Nielsen et al, 1986; Thorleifson and Wyatt, 1987).

Low carbonate concentrations in sediments offshore from the east and west coasts of Hudson Bay, in areas underlain by Paleozoic carbonates, indicate an increased input of sediment derived from bordering Precambrian outcrops. This distribution supports offshore sediment transport from the District of Keewatin and Nouveau Quebec into Hudson Bay, as previously proposed.

Depressed carbonate values in the muddy sediments of southern Hudson Basin may be a function of the grain size (Fig. 3.5), since carbonate minerals are primarily present in the silt fraction. These fine-grained sediments are dominated by the clay minerals and may represent post-glacial deposits in regional or local basins. These deposits would essentially bury glacially-derived material and mask regional dispersal trends in the surficial sediments.

4.8. SUMMARY

Sediment dispersal trends are best defined on the basis of compositional analysis of the gravel (2-5.6 mm) and fine sand (0.250-0.063 mm) fractions of the coarser grained seafloor sediments. The regional distribution of lithologies and heavy mineral assemblages attributed to distinctive sources onshore or underlying Hudson Bay indicate four major directions of sediment transport: (1) eastward and southeastward from the District of Keewatin to the Hudson Basin, southwestern Hudson Bay and Hudson Strait, (2) westward, southwestward and northwestward from Nouveau Quebec to Hudson Basin, Hudson Strait and the northern Manitoba coast, (3) eastward from central Hudson Bay to the Winisk Trough region, and (4) offshore from the southern coast of the bay. The dispersal trends are linked primarily to glacial processes, although post-glacial fluvial and/or marine current reworking of glacial sediment has been suggested for offshore trends in the southern bay.

The geochemistry of the clay-size fraction of surficial sediments from the periphery of the bay is consistent with the composition and dispersal of the coarser fractions. Concentrations of certain elements in deposits in northern, eastern, and western Hudson Bay can be linked to onshore anomalies and suggests sediment transport offshore from the Keewatin and Quebec coasts. In southern Hudson Bay, the concentration and distribution of elements is variable but generally compatible with the provenance of the coarser size fractions in the area. High concentrations of certain elements offshore in the Churchill River area indicate sediment transport by rivers.

In central Hudson Bay, the geochemistry of surficial deposits is dominated by elements associated with secondary processes, and appears to be a function of the physio-chemical conditions on the seafloor, primarily the low sedimentation rate as indicated by the generally fine grained texture of the sediments. Although elevated values of these secondary elements may be related to a local source, no definitive criteria supporting this hypothesis can be established. The apparent dominance of diagenetic processes in the sediments of central Hudson Bay masks regional, provenance-related, dispersal trends and provides little insight into the depositional process.

The main factors controlling the recognition of sediment transport paths in Hudson Bay surficial sediments are related to texture and the degree of sediment modification and/or burial by post-glacial deposits. Since the dispersal trends in coarser sediment types (sands, diamictons and sandy muds) in the bay are shown to be an extension of glacially-derived dispersal patterns seen on land, it follows that the deposits in the bay are, in all likelihood, glacially-derived or derived from glacial material with little moving or mixing. Therefore, sediment composition and provenance, based on gravel and sand analyses, has implications for the glacial history of the Hudson Bay region.

CHAPTER 5

DEPOSITIONAL FACIES: IMPLICATIONS FOR THE GLACIAL HISTORY OF HUDSON BAY

5.1 Introduction

Integration of textural, compositional and acoustic characteristics of seafloor sediments in Hudson Bay can be used to define facies and interpret probable depositional environments. Based on the distribution of these facies and an assessment of sedimentary processes affecting the arctic shallow marine environment, a model for sedimentation in Hudson Bay is proposed. The interpretation of glacial sediments has important implications for the glacial history of the Hudson Bay area, especially when considered in conjunction with the distribution of glacially-derived geomorphic features and ice flow indicators in and adjacent to the bay. From these relationships, a general framework for glaciation and deglaciation of the region can be considered.

5.2. Definition of Depositional Facies

Depositional facies in Hudson Bay, as outlined in Table 5, are based on the textural, compositional and seismic features of surficial sediments which distinguish them, one from another. Four main facies are proposed (Fig. 5.1).

The primary distinction between facies is sediment texture, specifically the proportion of sand and gravel. Since few depositional processes other than those associated with ice (either glacial or sea-ice) can transport coarse material to the centre of the bay, this division serves as a rough separation between sediments deposited by glacial processes or sea-ice rafting and those deposited by other means. The arbitrary division between facies is taken at 10% sand content (Types 1-3, Chapter 3), but muds with >1% gravel are indicated (Fig.5.1).

TABLE 5

DEPOSITIONAL FACIES OF SURFICIAL DEPOSITS, HUDSON BAY

	<u>Facies A</u>	<u>Facies B</u>	<u>Facies C</u>	<u>Facies D</u>
Location:	Northwestern quadrant, Hudson Bay. Water depth <180m	Dominates eastern half of Hudson Bay, occurring at all depths, most common <180m.	Southwestern quadrant and central Hudson Bay, depths <200m.	Patchy accumulations throughout bay, depths >90m. Covers seafloor in Hudson Basin and southeast Hudson Bay.
Sediment Types:	Diamicton, sorted sand and silty sand. Generally contains significant gravel fraction.	similar to Facies A.	similar to Facies A.	Fine-grained sediment (mud). A sub-facies (D1) has gravel content >1% total sample weight.
Composition:	Igneous/metamorphic and maroon volcanic /sedimentary rocks in gravel fraction; heavy minerals characteristic of Proterozoic and Archean shield areas. High percentages of grey/tan carbonate clasts and calcium carbonate (<0.063mm) in Fisher and Evans Strait.	Igneous/metamorphic and greywacke/ argillite clasts in gravel; heavy minerals characteristic of Proterozoic and Archean terrane. In central Hudson Bay, Paleozoic grey/ tan and pink/red carbonate clasts and siderite are also present.	Gravel fraction includes clasts of all rock types; heavy mineral suite characteristic of both Paleozoic and Proterozoic and Archean terrane.	When present, clast and heavy mineral composition is similar to adjacent coarse-grained sediment types. In clay-size fraction Co, Ni, Mn, Fe, and Zn values are commonly elevated.
Provenance and Dispersal:	Western provenance derived from sources in the District of Keewatin. Offshore dispersal from west to east to central Hudson Bay.	Eastern provenance, derived from sources in the Belcher Is. and Nouveau Quebec. In the central bay, derived from local Paleozoic rocks. Westward dispersal to central Hudson Bay and Hudson Strait. Eastward dispersal of pink carbonate clasts from central Hudson Bay.	Mixed provenance, derived from sources in eastern, western and central Hudson Bay. Dispersal complex, includes easterly transport from the District of Keewatin, easterly transport from central Hudson Bay, westerly and northerly from Nouveau Quebec and central bay.	Not applicable. High trace element concentrations suggest diagenetic processes. Provenance of coarse fraction, if present, is similar to adjacent coarser sediment types.

	<u>Facies A</u>	<u>Facies B</u>	<u>Facies C</u>	<u>Facies D</u>
Acoustic Character:	Surficial unit acoustically massive. Overlain by patchy accumulations of acoustically transparent to laminated material present in basins.	similar to Facies A.	similar to Facies A.	Facies is variable and appears as a thin acoustically massive unit, or acoustically transparent unit infilling depressions in seafloor, or conformably draped unit with parallel internal reflectors.
Seafloor Geomorphic Features:	Parallel iceberg scour widespread. Trends generally parallel bathymetric contours, minor corduroy features. Ridges, interpreted as moraines, present locally.	Parallel and random iceberg scour. Ice marginal and De Geer(?) moraines, localized unscoured areas and channel features present. Possible flutings.	Parallel and arcuate iceberg scour in central bay, random scour and moraine ridges present in southern bay. Buried sand waves offshore from Nelson River estuary.	Completely scoured in Hudson Basin. Parallel, arcuate and random scour. In nearshore areas and south Winisk Trough, facies is unscoured.
Other Features:	Seafloor photographs indicate a hard stoney bottom with occasional large faceted boulders. (Barber et al, 1981)	similar to Facies A.	similar to Facies A.	Soft, homogeneous mud. Organisms and trails present in shallow area.

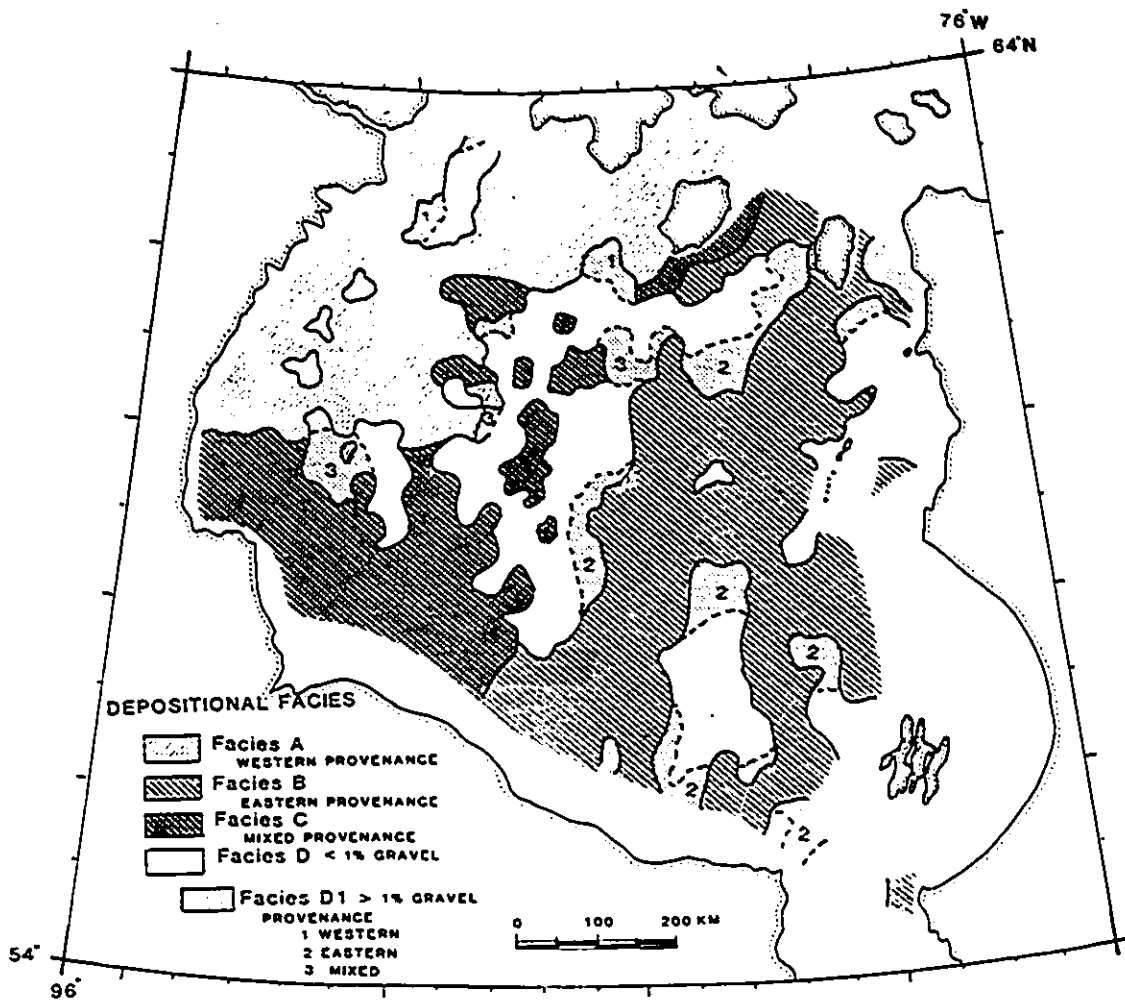


Figure 5.1: Depositional facies of surficial sediments in Hudson Bay. Criteria used to define facies are outlined in Table 5.

Within the coarser grained sediment types, facies are differentiated by composition. Clast lithologies and heavy mineral assemblages indicate the sediments are derived from three distinct source terranes. Sediments from sources in the District of Keewatin (Dubawnt Group lithologies and epidote-garnet-hematite heavy mineral assemblage) cover the western half of the bay extending offshore from the Keewatin coast to central and southern Hudson Bay and northward to Coats Island and Hudson Strait. Sediments derived from outcrops in eastern Hudson Bay and Quebec (greywacke/argillite clasts and Proterozoic heavy mineral assemblages) cover the seafloor in the southern, eastern and northern bay and Hudson Strait. The westward extent of material derived from Paleozoic formations outcropping in central Hudson Bay (red/pink carbonate erratics and siderite) coincides with sediment of eastern provenance. Eastward dispersal of siderite and red carbonate clasts from central Hudson Bay extends to the Winisk Trough and Henrietta Maria Arch. On a broad scale, however, sediments in the bay are shown to reflect deposition from essentially two opposing and, in some areas, overlapping dispersal systems.

5.3. Facies Interpretation

5.3.1. Coarse-grained Facies (A, B, C)

The coarse grained facies (A-C) in Hudson Bay are interpreted as glacial deposits, based on sediment texture and composition, particularly the dispersal trends of distinctive lithologies, heavy mineral assemblages, and, to a lesser extent, trace element concentrations in the clay fraction (Chapter 4). This conclusion is supported by the acoustic character of the surficial deposits and the presence of features interpreted as ice marginal and subglacial deposits on the seafloor in these areas (Chapter 2).

Sediment transport paths are indicated in Figure 5.2. Dispersal trends in seafloor sediments are consistent with

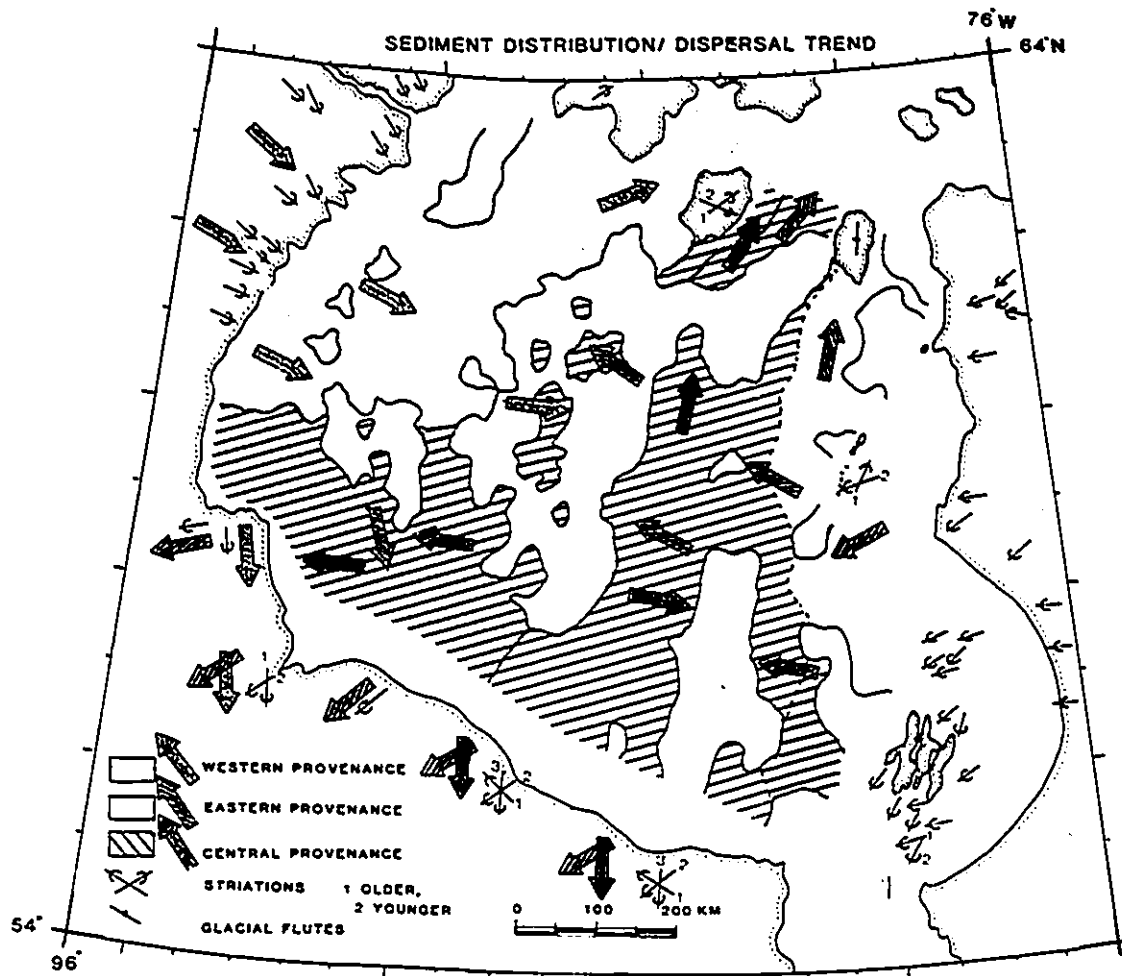


Figure 5.2: Relationship between dispersal trends and ice flow indicators in Hudson Bay and adjacent areas. Onshore data from Prest et al (1967); Kaszycki and Shilts (1979); Nielsen et al (1986); Dredge et al (1986); Wyatt (1987); Thorliefson (1989); and Aylsworth and Shilts (in press).

glacial flow directions observed onshore in areas adjacent to Hudson Bay. The distribution of Dubawnt erratics and associated heavy mineral assemblages and trace element compositions in tills indicates eastward ice flow from the District of Keewatin (Shilts et al, 1979; Shilts, 1980a, 1982, 1986; Paré, 1982), and southward to southeastward flow in sections exposed along the river valleys of southern Manitoba (Dredge et al, 1986; Nielsen et al, 1986).

Glacial flow indicators in eastern Hudson Bay exhibit westward to southwestward flow (Prest et al, 1967). Tills dominated by sediment of eastern provenance are exposed in the Hudson Bay Lowlands (Andrews et al, 1983 ; Wyatt, 1987; Thorleifson, 1989) and northern Manitoba (Nielsen et al, 1985; Dredge and Nielsen, 1985; Netterville, 1974) and also indicate deposition by southwestward ice flow (Fig. 1.6). Within seafloor deposits, dispersal trends of lithologies and heavy mineral assemblages derived from formations in eastern Hudson Bay indicate westward sediment transport from the Quebec coast across southern Hudson Bay. Northward dispersal of lithologies underlying the Richmond Gulf Embayment and outcropping on the Belcher Islands (greywacke/argillite) is recognized in central and north-central Hudson Bay and on Coats and Mansel Islands and parallels ice flow indicators present on Coats and Mansel Islands (Aylsworth and Shilts, 1987 a,b).

Tills containing red/pink Paleozoic clasts and siderite derived from outcrops underlying central Hudson Bay were deposited by southwestward and southward ice flow in western Hudson Bay Lowlands and northern Manitoba (Henderson et al, 1987). Seafloor sediment with this provenance indicates sediment dispersal westward, southwestward and northward from the centre of Hudson Bay in association with compositional trends of sediment derived from sources to the east. Eastward and southward dispersal of sediment from central Hudson Bay is also present in the region of the Winisk Trough. This flow is

believed to be a late glacial feature. The youngest tills in sections along the Winisk and Severn River valleys are dominated by sediment from central Hudson Bay, deposited by ice flow to the south (Wyatt, 1987; Thorleifson and Wyatt, 1987; Thorleifson, 1989).

Within the glacial and glaciomarine environment, sedimentary processes are varied and complex. This complexity may account for textural variations within the coarse-grained facies. Nevertheless, the sediment composition reflects that of the material entrained within the glacier and indicates the extent of glacial transport within the bay.

5.3.2. Fine-grained Facies (D)

Fine-grained facies dominate the deeper areas of Hudson Bay and are interpreted as glaciomarine or post-glacial marine deposits. Differentiation is difficult, however, and cannot be based solely on texture, composition, or acoustic signature. A coarse fraction may or may not be present in material deposited in either environment. Because of sea-ice rafting, the lack of a gravel component is not a definitive criterion for the recognition of post-glacial sedimentation in the central bay. Similarly, glaciomarine sediment interpreted from cores (Appendix B) includes laminated muds lacking dropstones (HU-87-040-001 and 004).

The geochemistry of fine-grained sediments deposited in central Hudson Bay tends to be enriched in those elements associated with secondary processes. Consequently, the composition reflects the physio-chemical conditions on the seafloor and cannot be related to a unique source area or depositional setting.

Within the fine-grained facies (D), the acoustic character of the sediment as interpreted from sub-bottom profiles (Josenhans et al, 1988) (Chapter 2: Fig. 2.4) varies widely and includes all facies types. In certain areas, particularly the Hudson Basin, the surficial unit is defined on the basis of its

lack of acoustic stratification and interpreted as till (Fig. 2.4). However, reworking by icebergs may significantly modify or destroy stratification, so the deposits could represent scoured glaciomarine sediment, or thin post-glacial marine deposits. It is reasonable to expect a more restricted distribution of post-glacial deposits in the seismic interpretation because geophysical equipment does not resolve mud veneers less than several meters thick.

Because of the lack of definitive criteria, no specific interpretation of the fine-grained sediment can be made. These deposits may be either post-glacial or glaciomarine. When a gravel fraction is present ($> 1\%$) (Facies D1) at sites in central Hudson Bay, the provenance generally reflects that of the adjacent coarse-grained facies (Fig. 5.1).

5.4. PROCESSES OF SEDIMENTATION AND SEDIMENT MODIFICATION

Although seafloor sediments in Hudson Bay are largely glacial, a sedimentation model cannot be proposed without some consideration of post-glacial processes of sedimentation and sediment modification. These processes result from the interaction among: (1) the fluvial systems, which control sediment supply and freshwater input into the basin; (2) ocean processes, which modify sediment through tidal, ocean and wave-induced currents; (3) annual sea ice cover, which may transport, and modify sediment, particularly in the nearshore environment; and, to a lesser extent, (4) eolian and (5) biogenic processes (Fig. 5.3).

5.4.1. Fluvial Systems

Models for fluvial sedimentation in the arctic marine environment indicate that inflowing sediment of all size fractions is transported offshore during the "summer" period as both suspended load and bed load (Gilbert, 1983; pg. 154) (Fig. 5.3a). Depending on sediment concentration, fine-grained suspended sediment and freshwater discharge overflow the denser

MAJOR PROCESSES OF SEDIMENTATION
AND SEDIMENT MODIFICATION

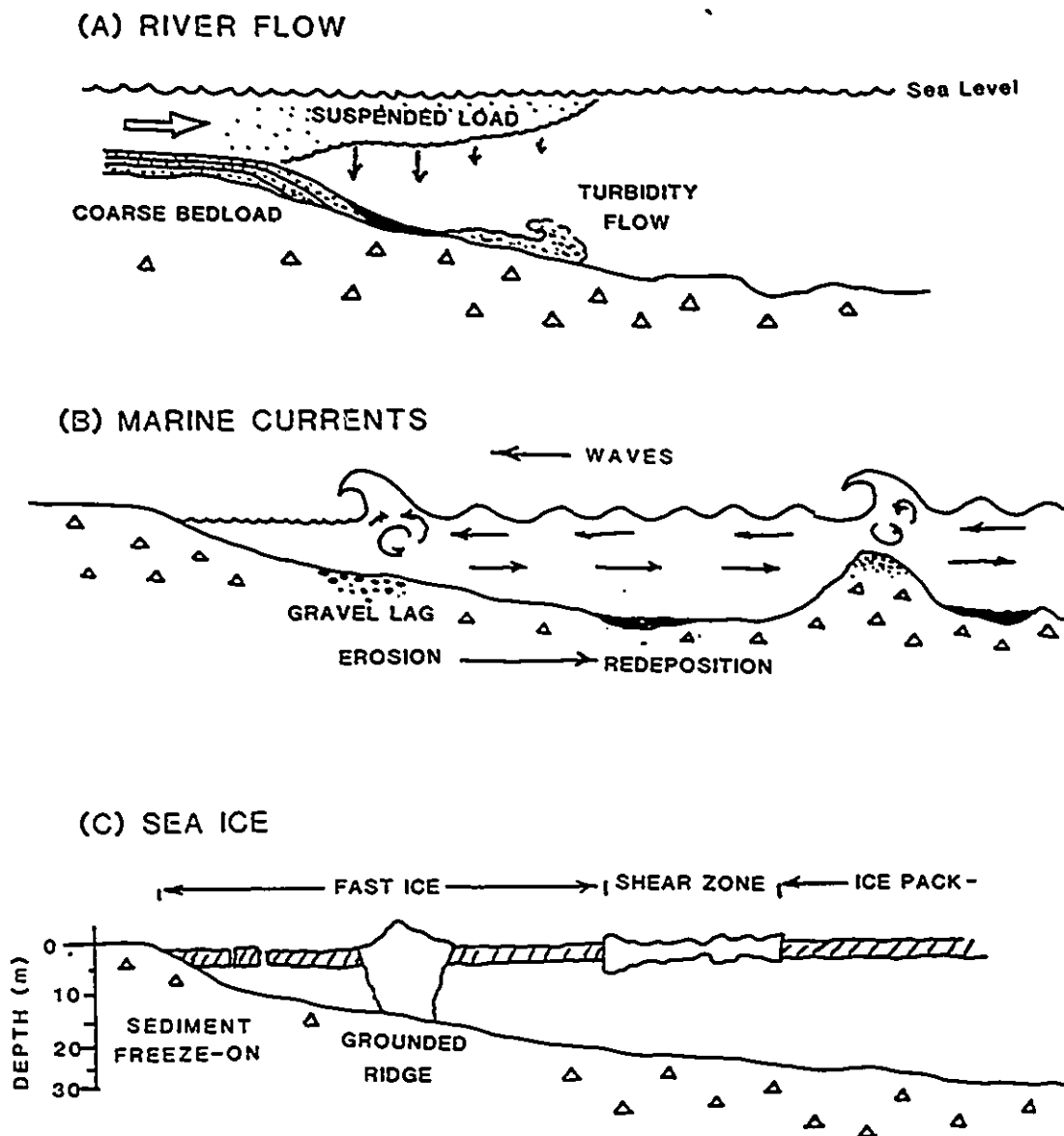


Figure 5.3: Major processes of sedimentation and sediment modification for shallow marine environment. (modified from Allen (1979), Walker (1984), and Drewry (1986)).

sea water. Fine particles flocculate as mixing occurs and settle out relatively rapidly due to increased particle diameter (Kranck, 1973; Gilbert, 1983).

The bed load or traction carpet of coarse grained sediment is rapidly deposited at the river mouth in the zone of expanding flow and decreasing velocity (Gilbert, 1983). Under certain conditions, coarse and fine grained material may continue downslope from the river mouths as mass flows and be deposited in the deeper parts of the basin (Blatt et al, 1980; Walker, 1984). The flows are primarily initiated by failure at a delta front and are dependant on the rate of sediment supply, slope of the basin margin, and/or the effects of tidal and wave action and floating ice (Walker, 1984).

Little is known about the nature of the sediment load of rivers discharging into Hudson Bay (Martini, 1986). The material is derived, to a large extent, from Quaternary deposits exposed along the river channels (Adshead, 1983c). On the Precambrian terrane of the eastern and western coasts of Hudson Bay, these deposits are thin and discontinuous with minor eskers and moraines (Gray and Lauriol, 1985; Shilts and Aylsworth, 1987). Consequently, the sediment supply to the fluvial systems in these areas is low. In the District of Keewatin, numerous lakes along the rivers trap sediment, further reducing sediment input into the bay.

As a result of post-glacial uplift, the major rivers of southern Hudson Bay (the Hudson Bay Lowlands) have eroded thick sequences of Quaternary sediments. Because of the large volumes of sediment available for transport, the extensive drainage basins of the rivers and the relatively longer annual "ice-free" conditions compared to more northerly regions, the rivers in the south must contribute the greatest sediment load to Hudson Bay. Small deltas have been recognized locally from air photos at the mouth of the South Knife River on the west coast of Hudson Bay, but, in general, deltas are absent (Martini, 1986). This

indicates that the amount of material carried by these rivers is also low and mass flow of sediment to deeper parts of the basin is insignificant.

Another possible mechanism for deposition of sand and coarser sediment offshore from rivers can occur during sudden high discharge at the time of spring break-up. Nelson (1982, p. 541) proposed this mechanism for deposits offshore from the Yukon River Delta on the Bering Shelf. Although damming of rivers by ice jams occurs in southern Hudson Bay every spring, the sediment appears to be distributed laterally across the floodplain (Martini, 1986).

Seafloor observations by both Leslie (1964) and Josenhans et al (1987) confirm the lack of significant deposits of post-glacial sediments in central Hudson Bay. It appears that the bulk of the fluvial sediment entering the bay is deposited nearshore, either along the lower reaches of the river channels (Martini, 1986) or parallel to isobaths, following transportation offshore. From textural data, moderately to well sorted, coarse grained sediments form a sandy tongue extending approximately 50 km offshore from the mouth of the Churchill and adjacent rivers (Fig. 3.3). The sorting and coarse texture of these nearshore samples probably results from deposition of the fluvial traction load. A similar "sediment plume" is also present offshore from Chesterfield Inlet. It is interesting to note that the sandy, well sorted sediments in both areas have, in general, a significant coarse (>2 mm) fraction. If the deposits represent modern fluvial sedimentation, as postulated, the coarser component must have also been transported and deposited through this process during periods of high discharge and/or by sea-ice.

5.4.2. Ocean Processes

Sedimentary processes operating in marine/ocean systems are most active in the shallow marine environment and result from the complex interaction of tidal, ocean and wind-driven currents

(Swift et al, 1971). Models for sedimentation in this environment are discussed by Swift (1970), Allen (1979) and Walker (1984) (among others) and are summarized in Fig. 5.3b. In areas characterized by a broad seaward-sloping shelf supplied with mixed sediments, grain size decreases offshore. Transport of the coarser size fractions (coarse silt, sand and gravel) is limited to the depth where the stress required to move the particles equals that exerted on the bottom by the combined bottom currents. Fine silt and clay are deposited in deeper water where turbulence induced by marine currents is incapable of maintaining the particles in suspension. The sediment is unlikely to be remobilized unless sudden storm surges or seasonal variations in tidal currents increase the maximum bed shear stress (Allen, 1979).

In Hudson Bay, both glacial sediment covering the seafloor and reworked Quaternary deposits entering the bay from the fluvial system are subjected to marine currents. The current regime is composed of a general cyclonic (anti-clockwise) surface circulation (Barber, 1968; Prinsenberg, 1986) and a tidally-induced component which is strongest along the northwestern and western coasts of the bay (Prinsenberg and Freeman, 1986). Wind-induced currents are more variable. The strongest winds occur from October to mid December and flow northwesterly to southwesterly over the western half of the region and westerly to southwesterly over the eastern (Maxwell, 1986, pg. 83). Consequently, the combined effect of these currents is most pronounced along the western and southwestern coasts of the bay.

Surficial sediments in these coastal areas show an offshore gradient of decreased sorting (Fig. 5.4) and mean grain size (Fig. 3.8). Textural variations along offshore profiles from the Keewatin coast (Fig. 5.5) indicate that these trends extend to approximately 100 m depth. In deeper water, the sand and

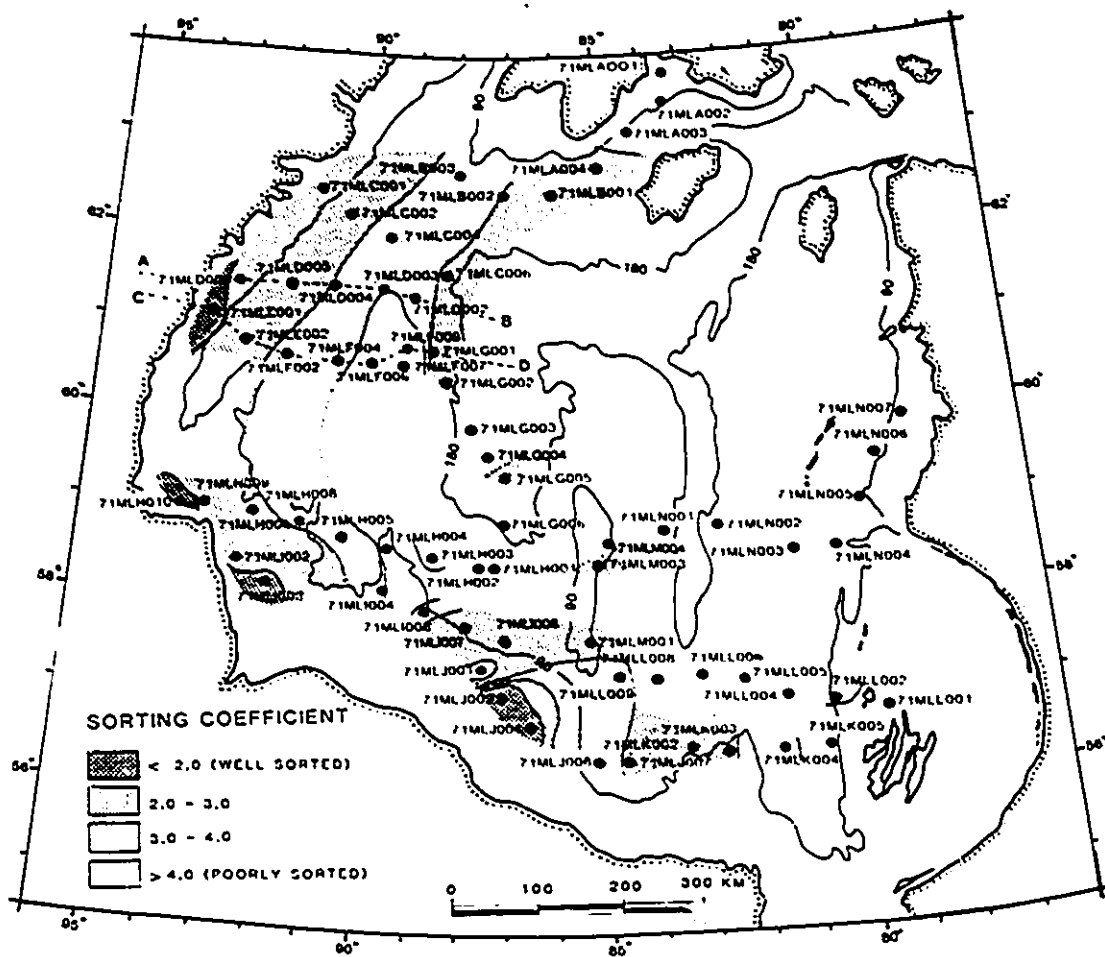


Figure 5.4: Variation in sorting, 1971 samples. Offshore profiles A-B and C-D are illustrated in Figure 5.5.

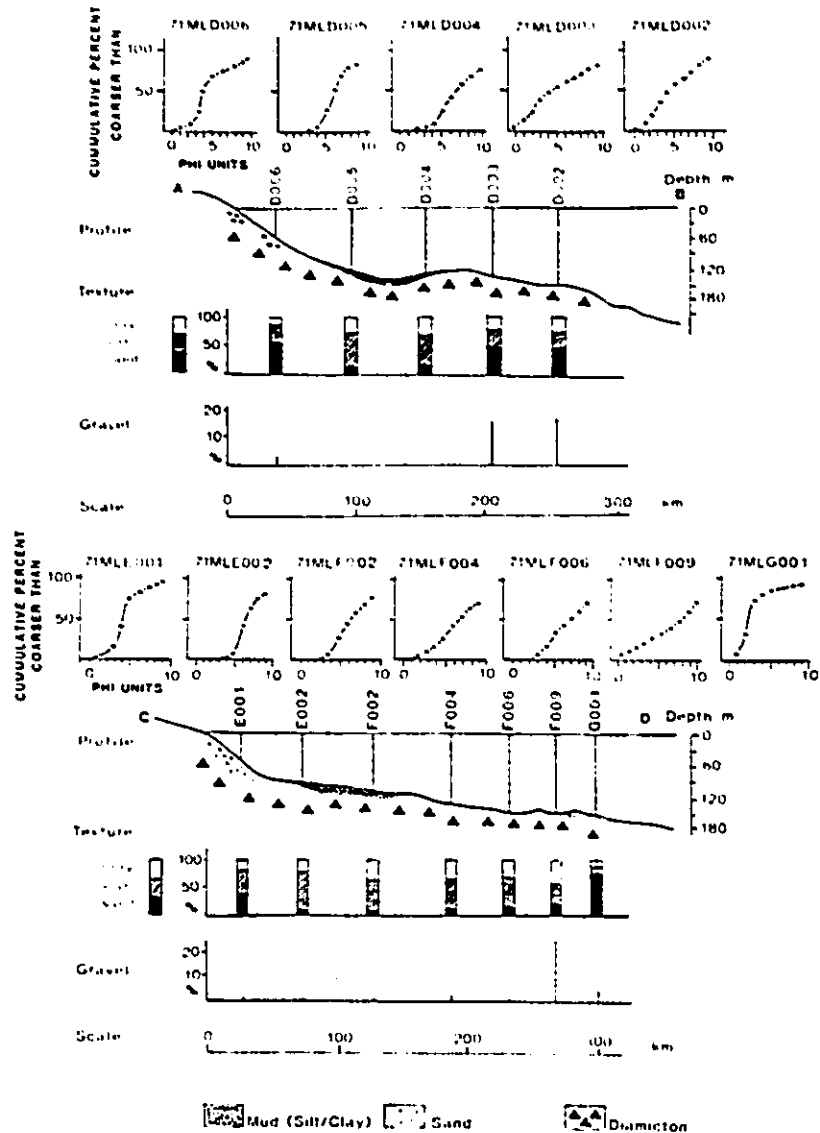


Figure 5.5: Offshore textural variation along profiles from western Hudson Bay. Locations shown in Fig. 5.4. Grain size variations are illustrated by cumulative frequency curves, sand:silt:clay ratios, and gravel (>2mm) proportion.

gravel component of the sediments increases and, with the exception of site 71MLG001, the sorting decreases.

The observed textural variations along the profiles may be explained by current modification of generally unsorted (glacigenic) sediment on the seafloor (Fig. 5.3b and 5.5). As bottom current velocities decrease with depth, the capability of these currents to erode and sort mixed sediment also decreases. Consequently, progressively finer grain sizes are removed from the seafloor deposit with depth and transported downslope until an equilibrium condition is established. Nearshore material (<100 m depth) essentially represents a lag deposit composed of the residual portion of the sediment and/or material transported a relatively short distance downslope. This situation would be expected for all areas of the bay where erosion predominates, including bathymetric highs extending above storm wave base. Finer grained material is transported seaward and alongshore and deposited locally in depressions where current velocities are lower, eg. Site 71ML D004 and D005 along Profile A-B (Fig. 5.5), or in central Hudson Bay (Fig. 3.5). In depths exceeding 100 m, sediment texture along the profiles changes. Diamictons predominate and fine grained deposits are lacking. In these areas, neither erosion nor deposition occurs (Nuorteva, 1988) and the surficial sediments may represent unmodified glacial deposits. Although there is evidence for current activity (eg. 71ML G001), the implication is that these deposits do not result from reworking by marine currents.

Inferences from oceanographic data suggest that the current regime is weaker along the eastern and southeastern coasts of the bay. Observations in these areas are more limited but, in general, offshore trends in sorting and mean grain size are not well defined (Fig. 5.3). From the previous discussion, it can be postulated that coarse sediments offshore also represent either an erosional lag at shallow depths or an unmodified glacigenic deposit in deeper waters.

5.4.3. Sea-ice Rafting

A significant ice cover is present in Hudson Bay approximately six months of the year (Larnder, 1968). From mid-December to April the bay is completely frozen over, although occasional, wind induced leads may form primarily along the western shore and adjacent to the Belcher Islands. The pack ice is in constant motion. Individual floes are large, with thicknesses ranging up to 5 m, and are characterized by a lack of sediment, nearly constant thickness and a level surface. Ice melting occurs within the bay through downwasting from the floe surface (Markam, 1986).

Sea-ice rafting has been proposed as an important mechanism for transport and deposition of sediment of all size fractions (Leslie, 1964; Pelletier et al, 1968; Pelletier, 1969; Pelletier, 1986) although few direct observations are available for Hudson Bay. Sedimentation models are developed from other areas where observations have been made (Fig. 5.3c) (Gilbert, 1983; Campbell and Collin, 1958; Barnes et al, 1982), although interpretations are constrained by the unpredictable nature of ice movement and sediment release. The bulk of sediment found in sea ice is incorporated in the littoral zone by the freezing of material to the ice-base, particularly in areas influenced by significant tides, and/or by tides and currents washing sediment onto the ice during break-up (Gilbert, 1983). This material consists predominantly of clays (Campbell and Collin, 1958; Clark and Hanson, 1983) and, to a lesser extent, coarser sediment (Rosen, 1979). During and prior to break-up, approximately 90% of the entrained sediment is released within a few hundred meters of where it was incorporated (Reimnitz and Barnes, 1974).

Pressure ridges formed within sea ice interact with the seafloor and rework the sediment by bulldozing and gouging (Reimnitz and Barnes, 1974). Marks made by sea ice keels are restricted to continental shelf areas shallower than 100 m and

reach their maximum concentration between depths of 18-30 m (Weeks et al, 1983; Drewry, 1986).

Based on these observations, it would appear that sediment deposition by sea ice is localized in shallow nearshore areas (<30 m deep) and concentrations of ice-rafted debris in offshore areas of Hudson Bay are minor. This conclusion is supported by observations of cores from the bay (Appendix B). Fine-grained sediments, interpreted as post-glacial deposits, may contain pebbles, although the proportion is generally low. Similarly, fine-grained deposits in Hudson Basin and the southern Winisk Trough (Fig. 3.2) rarely contain a gravel component. However, the most compelling argument against sea-ice rafting as a major factor in sediment transport is the dominance of locally-derived lithologies in the coarse-grained facies overlying the Midbay Bank (Fig. 4.4). Because there is no nearshore source for the abundant red/pink carbonate clasts, this sediment must have been eroded from the underlying bedrock and deposited by glacial processes.

5.4.4. Biogenic Processes

The seafloor of Hudson Bay hosts a fairly wide range of organisms to a depth of approximately 100 m (Pelletier et al, 1969). In these areas, biogenic sediment fixing through pelletization or agglutination may occur, thus reducing sediment transport by marine currents. The importance of these processes on sediment stabilization in Hudson Bay is unknown.

5.4.5. Eolian Processes

High velocity winds may carry silt, clay and fine sand from onshore areas into the marine environment. Eolian plumes have been observed in Alaska extending >60 km offshore (Molnia, 1983). This sedimentary process is not believed to be a significant factor in central Hudson Bay.

5.5. SEDIMENTATION MODEL

A proposed genetic model for sedimentation is shown in Fig. 5.6. Based on the previous discussion, post-glacial sedimentary processes are principally active in the nearshore environment and involve reworking of surficial deposits. The general conclusions emphasize the importance of glacial sediments as opposed to sea-ice rafted debris in determining sediment distribution in the bay:

- 1) Seafloor sediments are primarily glacial, deposited by glacially related processes, and represent till or associated subglacial or ice-marginal facies. Glacially-derived sediments predominate in shelf areas of the bay (<150 m depth) in regions dominated by coarser sediment types containing significant gravel percentages. In the fine sand and gravel fraction, dispersal trends of sediment derived from distinctive sources adjacent to the bay appear to be extensions of glacial dispersal patterns observed onshore.
- 2) Modern fluvial sediment is low and restricted to nearshore areas adjacent to the mouths of major rivers, particularly those in southwestern Hudson Bay. Sediment eroded and transported by the rivers is derived primarily from glacial deposits and represents an amalgamation of all eroded units (Adshead, 1983 a,b,c). Near the mouths of major rivers, local offshore trends may disrupt major glacially-derived dispersal patterns in the bay.
- 3) The dominant sedimentation process is the erosion and remobilization of fluvial and/or glacial deposits by marine currents. Although sediment reworking is extensive at depths <100 m, major glacially-derived dispersal trends are maintained in the coarser sediment types. Unscoured areas on Mansel and Midbay Bank (Fig. 2.16), central Hudson Bay, may result from the reworking of post-glacial sediment by marine currents.

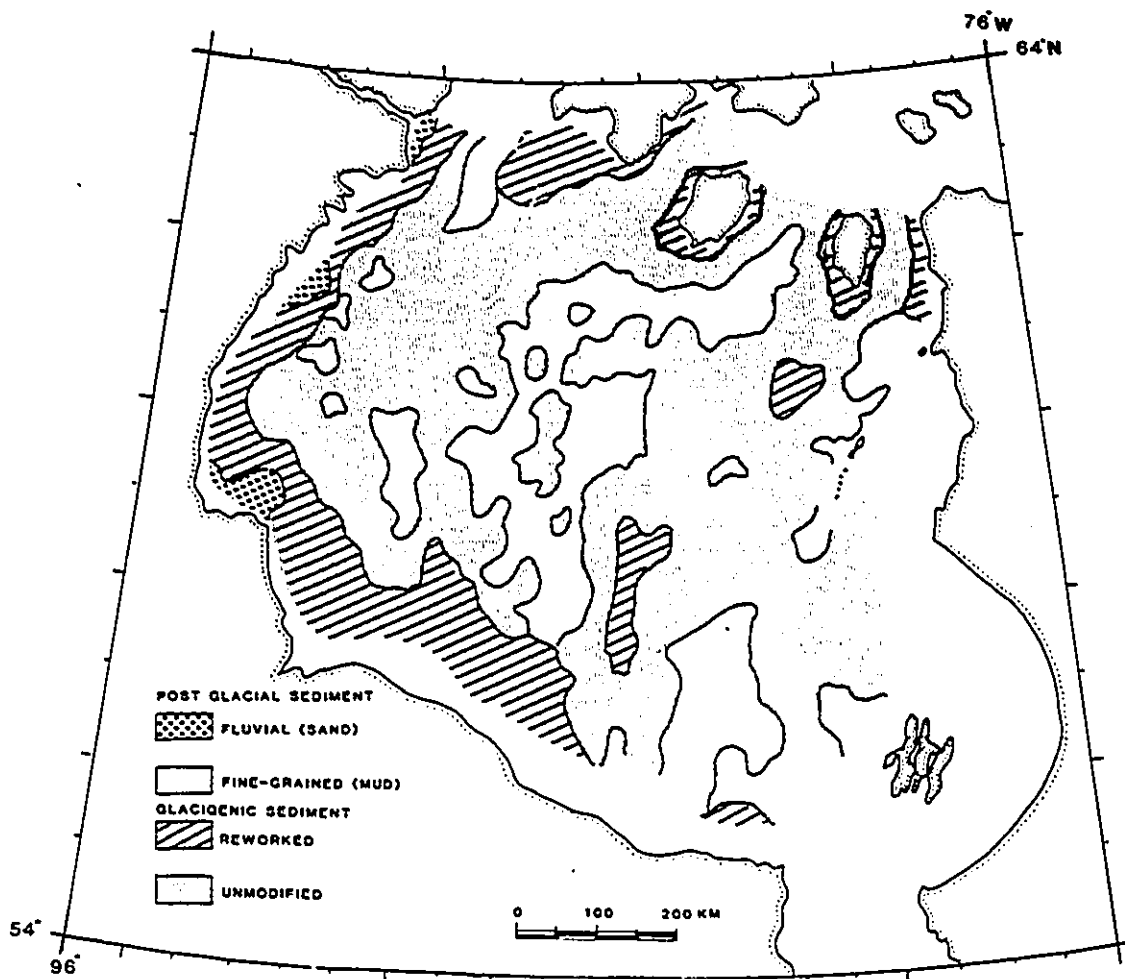


Figure 5.6: Sedimentation model for surficial deposits of Hudson Bay.

Over wide areas of the bay, at depths ranging from 90 - 150 m, there appears to be little sedimentation or erosion. In these areas, the surficial deposits represent unmodified glacial material.

- 4) Sedimentation is localized in depressions at depths exceeding 90 m but may be more widespread in deeper parts of the bay (>150 m). Differentiation between fine-grained sediment deposited in the distal glaciomarine and post-glacial marine environment is impossible, since diagenetic processes tend to dominate sediment composition. To a large extent, post-glacial sediments in central Hudson Bay may result from the erosion and remobilization of nearshore glacial deposits.
- 5) The effects of sea-ice rafting are most pronounced in nearshore areas (<30 m) and are minor in central Hudson Bay.
- 6) Biogenic and eolian processes are not believed to affect sedimentation significantly.

5.6. IMPLICATIONS FOR GLACIAL HISTORY OF HUDSON BAY

The relationship among ice flow directions observed onshore, dispersal trends in glacial sediment (Fig. 5.2) and geomorphic features observed on the seafloor (Josenhans et al, 1988) (Chapter 2) (Fig. 2.16), shown in Figure 5.7, has implications for the glacial history of Hudson Bay.

5.6.1. Glaciation

Dispersal trends and onshore ice flow features indicate glaciation from two opposing centres. The distribution of lithologies and heavy mineral assemblages derived from sources in the District of Keewatin denotes ice flow from west to east across western Hudson Bay, north to Coats Island and Hudson Strait, and southeast into northern Manitoba. Sediment dispersal from Proterozoic outcrops along the eastern coast indicates westward and southwestward ice flow extending into the Hudson Bay Lowlands and the Hudson Basin, and north to Coats Island and

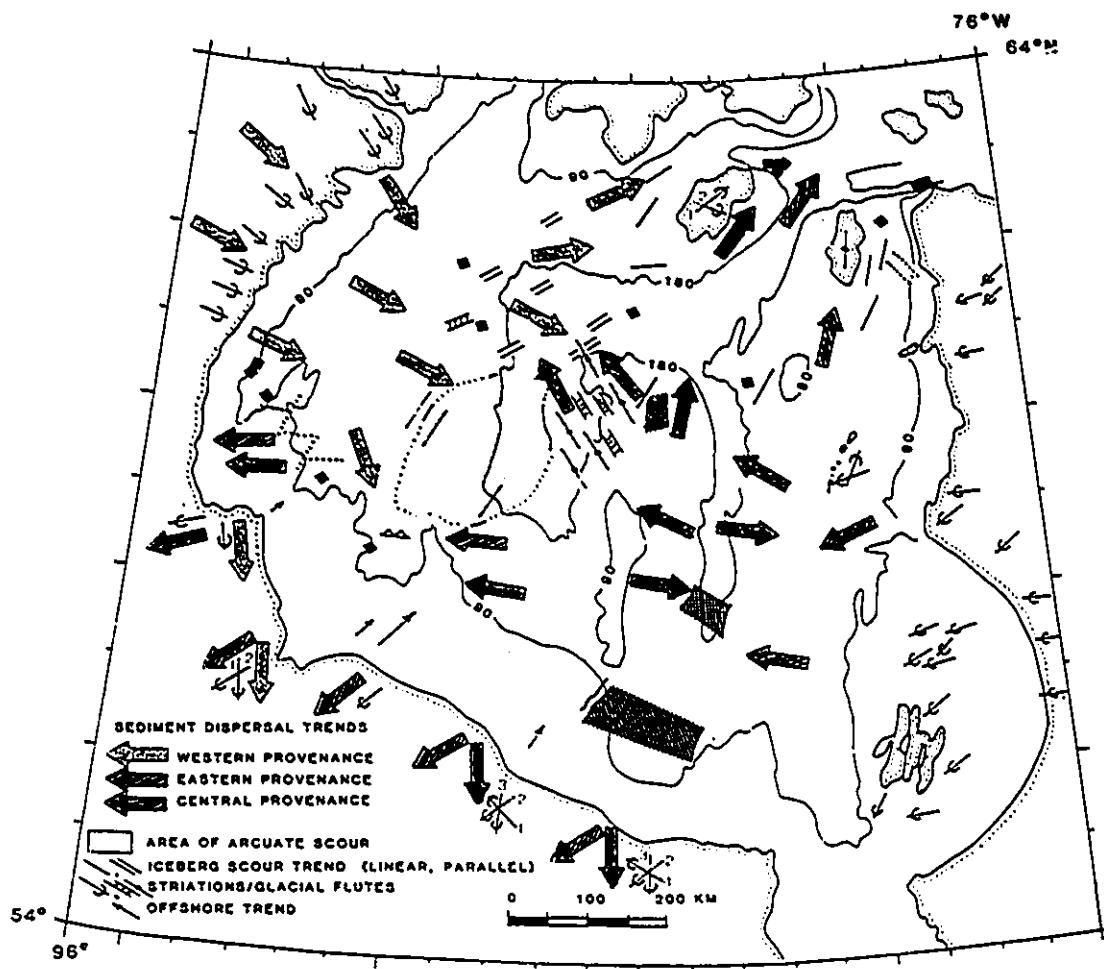


Figure 5.7: Glacial flow trends and landforms in and adjacent to Hudson Bay. Extended legend for seafloor geomorphic features given in Fig. 2.16. Onshore data from Prest et al (1967); Kaszycki and Shilts (1979); Nielsen et al (1986); Dredge et al (1986); Wyatt (1987) and Thorliefson (1989).

Hudson Strait incorporating material derived from central Hudson Bay. These trends parallel the orientation of glacial flutes observed on the seafloor.

The zone of confluence between the two dispersal systems includes the channel between Coats and Mansel Islands, the Hudson Basin and southwestern Hudson Bay. This area is characterized by glaciogenic sediment of mixed provenance which may result either from a shifting boundary between the two glacier systems and the recycling of previously deposited sediment, or the deposition of glaciomarine sediments derived from the two ice sheets. Stratigraphic sections along the Knife and Churchill Rivers, in northern Manitoba, support the first hypothesis and indicate a complex relationship between ice flow from two directions (Dredge et al, 1986; Fig. 1.6). Further east, the composition and ice flow indicators in tills along the Nelson River show that glaciation by ice flow from a centre in the District of Keewatin preceded several southwesterly advances of ice depositing tills of eastern provenance (Nielsen et al, 1986). There is no evidence of southeastward ice flow in sections along the Severn or Winisk River systems (McDonald, 1969; Wyatt, 1987; Thorleifson; 1989).

Dispersal trends of sediment derived from sources in central Hudson Bay indicate eastward ice flow from the Midbay Bank extending to the Winisk Trough and Henrietta Maria Arch area. No evidence of eastward glacier flow has been observed on the Belcher Islands. This dispersal trend is believed to result from changes in the ice sheet which postdate those prevailing during the last glacial maximum because of the distribution of sediment of eastern provenance across southern Hudson Bay, and the Hudson Bay Lowlands, and the following onshore observations:

- 1) The provenance and fabric of the youngest till exposed in sections along the Severn and Winisk River valleys reflects deposition by ice flowing from central Hudson Bay (Fig. 1.6). This unit overlies the regional till and has been

interpreted by Wyatt (1987) and Thorleifson (1989) as an ice stream deposit, localized in a depression and flowing out of Hudson Bay.

- 2) In the James Bay area, Veillette (1986) attributes converging ice flow from opposing dispersion centres on either side of the Harricana Interlobate Moraine (Fig. 1.7) as resulting from drawdown within an ice mass sometime after the last glacial maximum. The morainal deposit extends northward into James Bay.
- 3) Based on striation relationships in the Ottawa Islands, Andrews and Falconer (1969) proposed the development of a zone of separation and/or an ice free corridor redirecting glacier flow toward the Winisk Trough during deglaciation.

5.6.2. Deglaciation

The majority of features preserved on the seafloor have been interpreted as forming during the deglaciation of Hudson Bay (Chapter 2). Because of the size and distribution of scour features, it appears that deglaciation was centred in the deeper parts of the bay at the confluence between ice flowing from centres in the District of Keewatin and Nouveau Quebec.

Within this zone of confluence, arcuate scours cover the seafloor in parts of Hudson Basin. These scours are impressive, formed by large tabular icebergs, and confined to a zone several hundred kilometres wide (Fig. 5.6). Ice-flow features surrounding this zone indicate convergent flow such as might be expected during the opening of the bay. The area of arcuate scour has been interpreted as the southward extension of an embayment or calving bay initiated in Hudson Strait with the scour formed by iceberg movement within the enclosed region in response to tidal forces (Josenhans et al, 1988).

Alternatively, the formation of the arcuate scours may be linked to major turbulence within a calving bay during cata-

strophic drainage of Lake Agassiz. The position of the area of arcuate scour also coincides with significant offshore dispersal of siderite near the mouth of the Nelson River (Fig. 4.12), and the well developed sand waves observed on sonographs (Fig. 2.14). At present, the latter hypothesis is the preferred interpretation.

Moraines interpreted from sidescan sonar records indicate possible ice marginal positions (Fig. 5.7). Preliminary observations of moraine distribution indicate ice margin stabilization off Coats Island, the Ungava coast and adjacent to the Winisk Trough and Hudson Basin, and support the proposed extension of a calving bay in Hudson Strait into central Hudson Bay in these areas. Similarly, moraines in the southwestern bay indicate possible areas of glacier stabilization during continuing ice recession, possibly following drainage of the proglacial lakes.

Large areas of the Hudson Bay seafloor are scoured by icebergs, although the size, degree and style of scour varies (Table 2, Chapter 2). Compared to features in the zone of arcuate scour, iceberg scours in other areas of the bay are small and appear to be bathymetrically controlled. This suggests formation during a later stage of deglaciation. The subparallel to parallel scours in northwestern and central Hudson Bay indicate tightly controlled ice movement. Because sediment dispersal trends in this area appear to cross-cut scour trends, sediment transport may be controlled largely through glaciation. Compositional trends associated solely with iceberg rafting during deglaciation would be difficult to recognize on the regional scale of this study. Nevertheless, the low and intermittent distribution of red/pink carbonate and grey-wacke/argillite erratics in the sediments of the northwestern quadrant, an area dominated by material derived from sources in the District of Keewatin, may represent iceberg rafted debris.

In areas of the bay affected by random iceberg scour, the possibility exists for deposition of sediment of wide-ranging provenance. Constraints on berg movement and, consequently, sediment transport in these areas, are a function of berg size, marine currents and the configuration of the ice margin. Although several regions of random scour are present in the bay (Josenhans and Zevenhuisen, 1988), no significant area of sediment mixing has been recognized through compositional analysis other than those associated with glaciation. This lack of mixed provenance within large parts of the bay and the generally thin Quaternary cover implies either little sediment transport by icebergs and/or rapid deglaciation of the bay.

5.7. SUMMARY

The sedimentation model proposed for the surficial deposits of Hudson Bay (Fig. 5.6) emphasizes the importance of glacially-derived material and post-glacial processes of sediment modification. Variations in sediment composition within glacial deposits indicate that Hudson Bay was glaciated by ice flowing from two dispersal centres. Material derived from sources in the District of Keewatin covers most of western Hudson Bay, and sediment containing lithologies and heavy mineral assemblages characteristic of rocks outcropping east of the bay extend across eastern and southern Hudson Bay. The zone of confluence between the two dispersal systems extended from Coats Island in the north to northern Manitoba. It is postulated that this zone would have been a topographic low in the ice surface, and therefore acted as the locus for deglaciation through the formation of a calving bay, and ultimately for northward drainage of proglacial Lake Agassiz.

During deglaciation, the Winisk Trough may also have served as the focus for ice streaming (Wyatt, 1987; Thorleifson, 1989) and/or calving bay formation (Andrews and Falconer, 1969; Dyke et al, 1982). The resulting changes in ice sheet profile

isolated part of the Nouveau Quebec sector of the Laurentide Ice Sheet over central Hudson Bay. Ice flow from this centre dispersed sediment toward the calving bays and the ice margin to the south.

The lack of thick Quaternary deposits and significant mixing of sediment of varying provenance over large areas of the seafloor indicates that the disintegration of the Hudson Bay ice mass was rapid and/or the ice was sediment poor.

CHAPTER 6

LATE WISCONSIN AND HOLOCENE HISTORY, HUDSON BAY

6.1. Introduction

Up to the present, there has been a general lack of information on the glacial sediments and landforms underlying Hudson Bay. The Quaternary geology of this region is important, however, because it occurs in the centre of the area occupied by the ice sheets which covered North America during the Quaternary. Models and reconstructions of the Late Wisconsin Laurentide Ice Sheet, extrapolated from onshore observations and analogy with modern continental-scale glaciers, all emphasize the significance of the region as the site of glacial inception and/or deglaciation. The conclusions derived from these different approaches vary considerably and are not always compatible. With the recognition of glacially-derived depositional facies and geomorphic features on the seafloor of Hudson Bay, it is now possible to re-evaluate present models for the configuration and dynamics of the Laurentide Ice Sheet and propose a series of stages in the glacial history of the Hudson Bay area.

6.2. Configuration and Dynamics of the Laurentide Ice Sheet

Models for the inception and growth of the Laurentide Ice Sheet differ primarily in the interpretation of the number, location and inter-relationship of ice centres formed during glaciation (Fig. 6.1).

Proponents of a single-centre model postulate development of a stable ice dome centred over Hudson Bay. Within this model, two basically different theories of glacial inception have been presented:

- 1) a marine based ice sheet which formed in situ through development of an ice shelf centred in Hudson Bay (Hughes

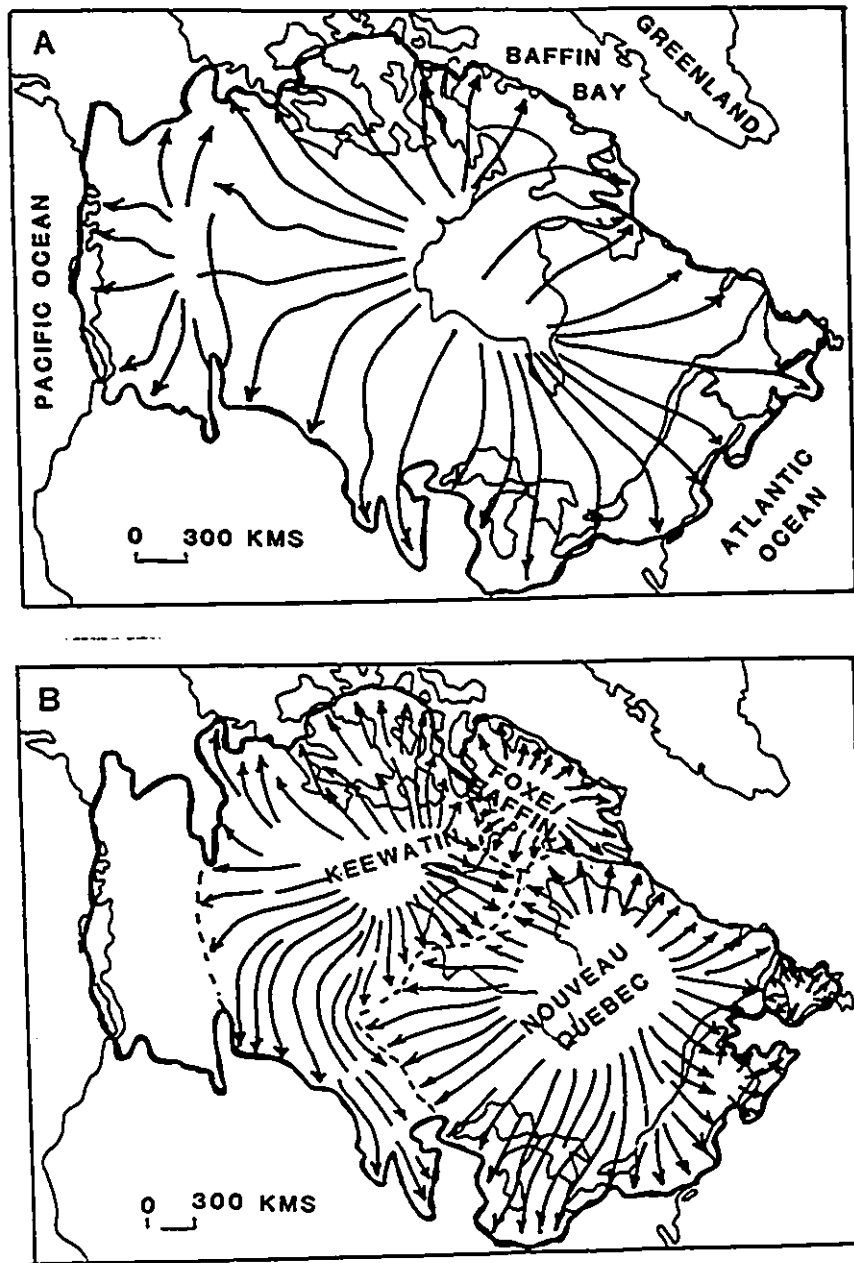


Figure 6.1: Comparison of models for the inception and growth of the Laurentide Ice Sheet. Arrows indicate ice flow paths. Dashed lines represent approximate boundaries between ice from different source areas.

A. Single dome model (from Denton and Hughes, 1981a) B. Multiple dome model (after Prest, 1984).

et al, 1977; Mayewski et al, 1981; Denton and Hughes, 1981a,b) or

- 2) a terrestrial based ice sheet which formed in the highlands of eastern North America and migrated windward until centred in the emergent Hudson Bay (Flint, 1943; Lee et al, 1957; Lee, 1959b, 1968; Sugden, 1977).

Other workers propose a multi-dome model with ice sheet growth resulting from the coalescence of several centres of ice accumulation. This model is supported by field observations of glacial flow indicators and dispersal trends (Tyrrell, 1898, 1914; Prest, 1970, 1984; Shilts, 1980a, 1982, 1985, 1986; Dyke et al, 1982; Andrews et al, 1983; Dyke and Prest, 1987) and glaciological modelling (Fisher et al, 1983; Boulton et al, 1985), although the number and importance of ice flow centers varies among workers.

Prest (1970) and Dyke and Prest (1987) subdivide the Laurentide Ice Sheet into three sectors with major flow components east, west and north of Hudson Bay in the District of Keewatin, Quebec/Labrador and Baffin Island, respectively. Inception is thought to have centred over these sectors through "instantaneous glacierization" induced by atmospheric changes resulting in increased precipitation and lowering of the snow line (Ives et al, 1975; Andrews and Mahaffy, 1976).

Rather than one extensive ice sheet, Tyrrell (1914, 1935) postulated three separate glaciers which grew and receded independently; one situated in the District of Keewatin (Keewatin Glacier), another in Quebec/Labrador (Labradorean Glacier), and a third centred in northern Ontario (Patrician Glacier). With advances in dating techniques, however, all present models acknowledge the Laurentide Ice Sheet as a single dynamic system, involving shifting ice centres in response to glaciological, topographic, oceanographic and climatological factors.

The single dome theorists postulate separation into, at least, two ice centres situated in the District of Keewatin and

Ungava Peninsula during the later stages of glaciation and deglaciation. Similarly, proponents of the multi-domed theories recognize changes in ice flow directions associated with major ice divides through time and, in some cases, several episodes of glacial build-up and retreat. There is evidence for a gradual shifting of Labradorean ice flow progressively northwestward (Low, 1900, 81D; Klassen and Bolduc, 1984; Bouchard and Martineau, 1985; Bouchard and Marcotte, 1986), development of an outflow centre over Hudson Bay (Vincent and Hardy, 1977; Dyke et al, 1982), and early ice flow centres southeast (Lee et al, 1957) and north (Taylor, 1956) of the Keewatin Ice Divide.

6.3 Model for Glaciation and Deglaciation

6.3.1. Glaciation

Dispersal trends in the glacial sediments of Hudson Bay support the multi-dome hypothesis for the configuration of the Laurentide Ice Sheet. There is no evidence for sediment transport east or west from central Hudson Bay onto the mainland. Ice flowed from centres in the District of Keewatin and Nouveau Quebec with the shifting zone of confluence between the two ice masses extending from Hudson Strait to northern Manitoba. A third dispersal centre situated over Foxe Basin has been postulated (Prest, 1984). Although high carbonate values in Evans and Fisher Straits may be related to this ice flow, no other supporting evidence has been recognized in the surficial deposits of the bay.

Ice flow directions on islands in northern Hudson Bay, Hudson Strait and northern Ungava Peninsula, and the dispersal trends of erratics in northern Hudson Bay show that ice flowed from the bay and along Hudson Strait (Prest et al, 1967; Andrews and Miller, 1979; Shilts et al, 1979; Shilts, 1982, 1985; Dyke and Prest, 1987). Supporting evidence includes the recognition of carbonate tills (Clark, 1985) and an intensely scoured zone (Andrews, 1987) along the southern coast of Baffin Island. This

flow appears to have been localized at the confluence of ice flowing from the various dispersal centres along a topographic low in the ice sheet profile.

The distribution of distinctive Dubawnt Group erratics from the District of Keewatin (Kaszycki and Shilts, 1979; Shilts, 1982; Aylsworth and Shilts, in press), and stratigraphic sections in the Hudson Bay Lowlands (Nielsen et al, 1986; Dredge et al, 1986) indicate that Keewatin Ice extended at least as far east and southeast as Coats Island, Hudson Basin and the southern coast of Hudson Bay between the Nelson/Hayes and Severn River systems. Because the oldest till (Illinoian(?)) exposed along the Nelson River is enriched in Dubawnt erratics (Fig. 1.6) (Nielsen et al, 1986), it is assumed that ice flow into this area from the District of Keewatin preceded southwestward flow from the Nouveau Quebec Ice Divide (Fig. 6.2).

The last major regional glacial event preserved in stratigraphic sections in the Hudson Bay Lowlands, northern Manitoba and northern Ontario indicates ice flow to the west, west southwest, and southwest from a dispersal centre in Nouveau Quebec (Fig. 1.6). The composition of the surficial sediment of southern Hudson Bay reflects this flow configuration. Sediment with an eastern provenance extends across eastern and southern Hudson Bay to the Hudson Basin, and possibly west of the basin (Fig. 4.5). The westward extent of greywacke dispersal in the surface tills of northern Manitoba is the Leaf Rapids interlobate moraine (Fig. 1.7) (Kaszycki and Dilabio, 1986). Erratics derived from the Belcher Islands also extend northward from the source area toward Hudson Strait and are present in tills of both Coats and Mansel Islands (Aylsworth and Shilts, in press). This ice flow configuration is shown in Fig. 6.3. The model is similar to that of Shilts (1980, 1982, 1985) and Prest (1984) and represents glacial flow prior to deglaciation (up to approximately 11,000 yr BP).

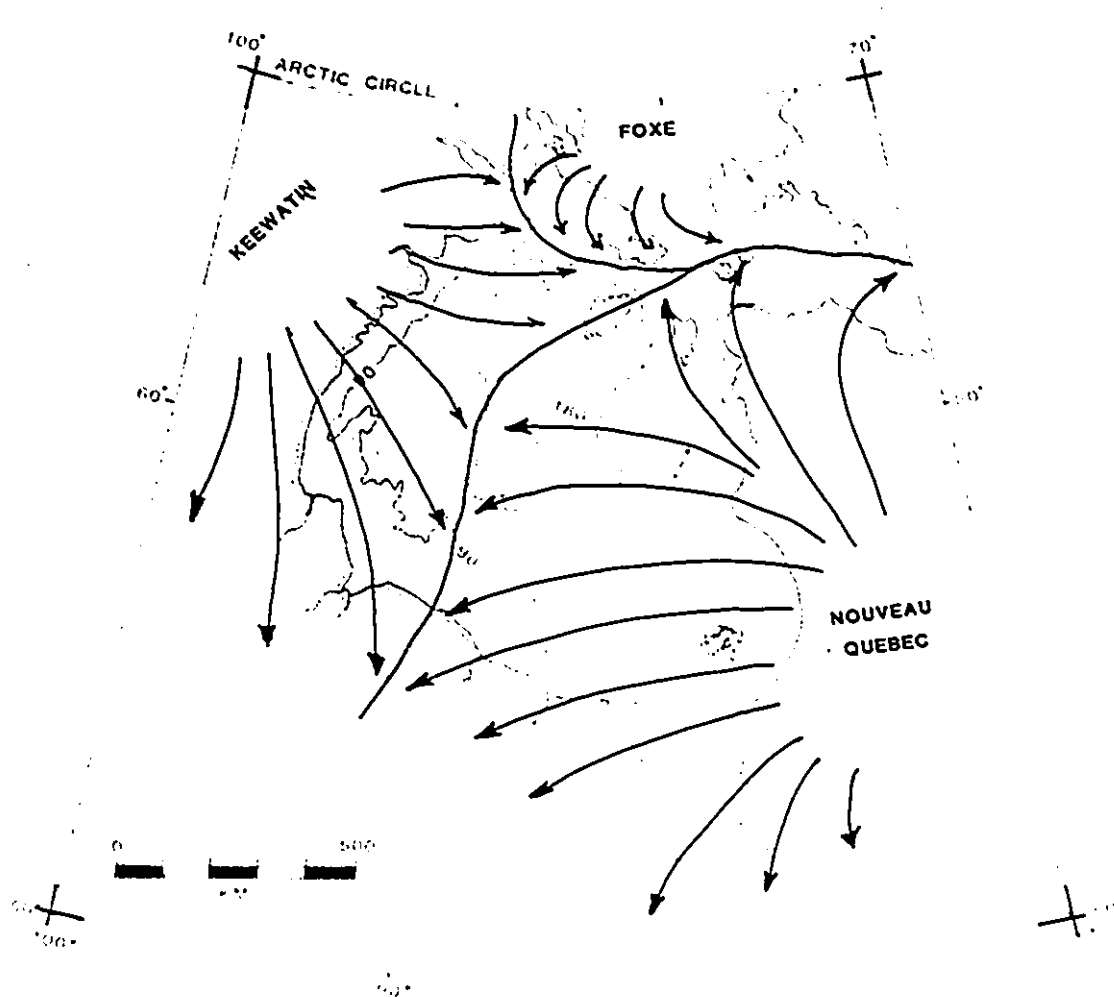


Figure 6.2: Possible ice flow early in the glacial history of Hudson Bay area. Flow from a Keewatin centre extends into the Hudson Bay Lowlands. Stratigraphic evidence from the Nelson River suggest this particular configuration may be Illinoian or Early Wisconsin (Nielsen et al, 1986).

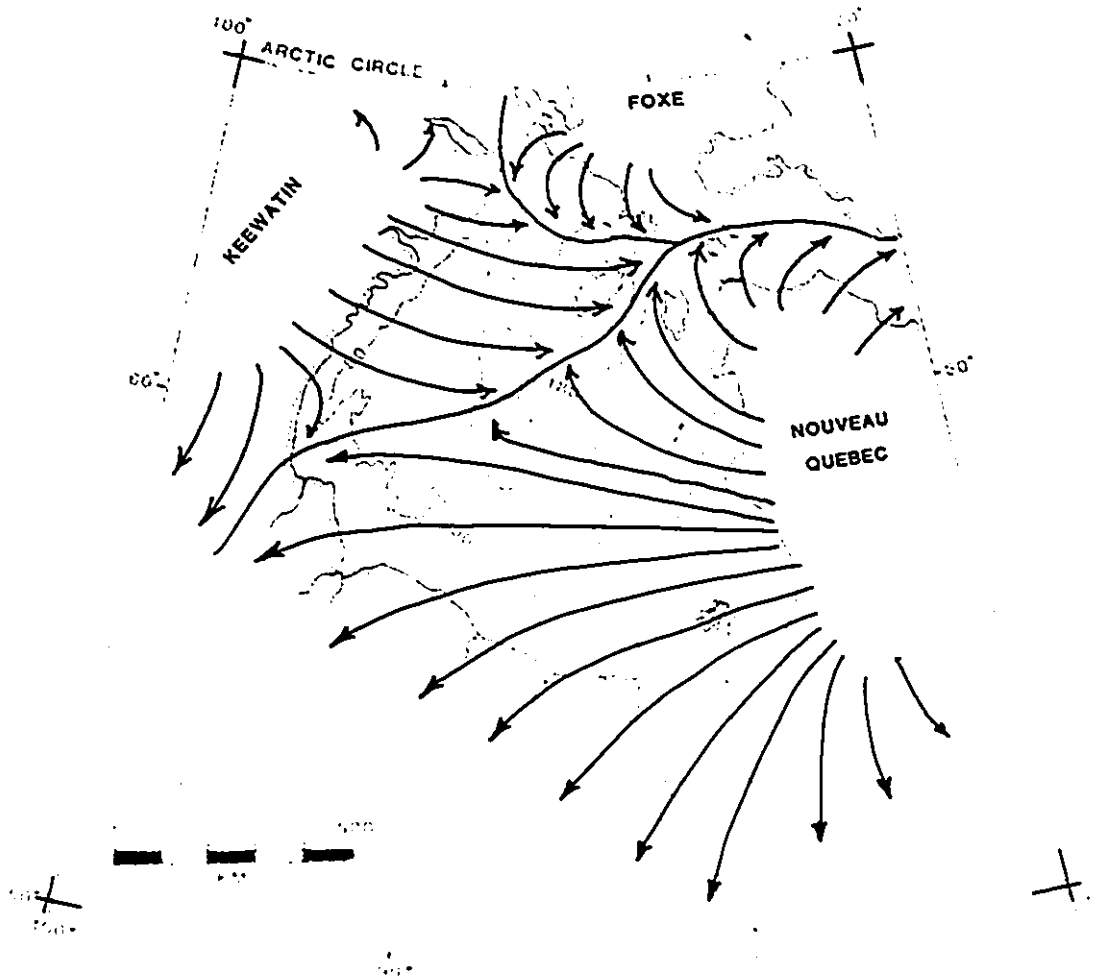


Figure 6.3: Possible ice flow during maximum extent of the Laurentide Ice Sheet. Note how the zone of confluence has shifted from Figure 6.2.

Speculative paleogeographic maps encompassing 18,000 to 11,000 yr BP (Dyke and Prest, 1987) suggest the presence of two ice domes, one in the District of Keewatin and the other west of James Bay and the Belcher Islands, joined by an ice divide across northern Ontario and northern Manitoba which migrated north through time to the Hudson Bay Lowlands and southern Hudson Bay. An ice flow centre south of Hudson Bay is also postulated in computer simulated models of the Laurentide Ice Sheet (Fisher et al, 1985). Offshore transport of erratics in southern Hudson Bay, ascribed here (Chapter 4) to fluvial and glaciofluvial processes, could be a manifestation of glacial flow from this centre, but there is no evidence of northward flow in any Late Wisconsin tills exposed in the Hudson Bay or James Bay Lowlands (Fig. 1.6). Tills, interpreted as Early Wisconsin, exposed along the Severn River, indicate northwestward ice flow from a dispersal centre east of James Bay (Wyatt, 1989; Thorleifson, 1989). Variations in fabric and till composition up section indicate a gradual migration of this ice flow centre into northern Quebec resulting in increased input of Belcher Island erratics.

6.3.2. Deglaciation

The proposed history of deglaciation for the Hudson Bay region is illustrated in Figures 6.4-6.7. Temporal control is poor. The interpretation is speculative and based on facies distribution and the spatial relationship between glacial dispersal trends and geomorphic features on the seafloor and in areas adjacent to the bay.

Stage 1: Development of a Calving Bay in Hudson Strait
Deglaciation of Hudson Bay is linked to the opening of Hudson Strait and the expansion of the sea into the centre of the Laurentide Ice Sheet (MacDonald, 1969).

The oldest ^{14}C ages of shells in marine sediments from the Deception Bay area, northern Ungava Peninsula range from 10,450 \pm 250 yr BP (I-488) (Matthews, 1967) to 9800 \pm 220 (Beta-

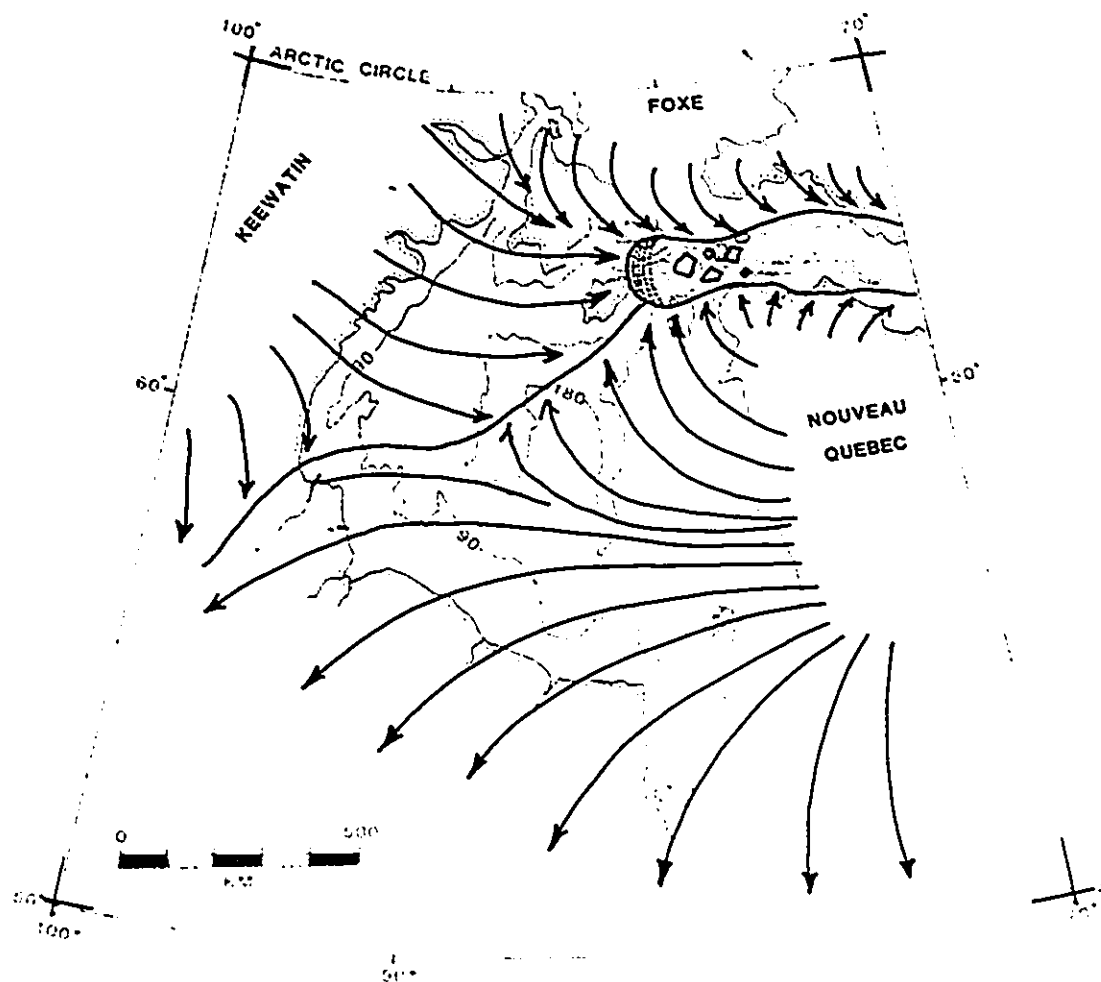


Figure 6.4: Deglaciation Stage 1: Development of a calving bay in Hudson Strait.

11121) and 9610±140 yr BP (Beta-13861) (Lauriol and Gray, 1987). Therefore, at least part of Hudson Strait must have been ice free by this time (9600 - 10,400 yr BP).

Proposed mechanisms for ice retreat have been associated with the disintegration of ice shelves in Hudson Strait (Denton and Hughes, 1981a; Boulton et al, 1982) leading to rapid calving, grounding-line retreat, and enhanced drawdown of the ice sheet in Hudson Bay. Any increase in sea-level or decrease in ice thickness, as might result from circulation changes and warming of the North Atlantic Ocean could trigger grounding line retreat (Boulton et al, 1982), and result in the eventual establishment of a new equilibrium grounding line (Robin, 1979; Thomas, 1979a,b).

There is evidence for ice flow or ice streaming toward Hudson Strait in the surficial deposits of Hudson Bay. The northward dispersal of erratics in northern regions of the bay trends toward Hudson Strait and, in general, parallels ice flow indicators observed onshore (Fig. 5.2). In addition, the thick glaciomarine sequences in Hudson Strait and the lack of similar deposits in Hudson Bay, the high carbonate percentages in Fisher and Evans Strait and the moraines between Coats and Southampton Islands and between Mansel Island and the Ungava coast (Fig. 2.8 and 2.16) all suggest that the new equilibrium position was established in northern Hudson Bay (Fig. 6.4). The calving bay gradually extended into the channel between Coats and Mansel Islands. Aylsworth and Shilts (in press) interpret eastward trending ice flow indicators, which cross-cut the main NE-SW glacial flow trend on Coats Island, as a reorientation of flow initiated by the opening of a calving bay in the central channel between the islands.

Stage 2: Extension of Calving Bay into Hudson Bay

With the ice margin temporarily stabilized in the northern region (Fig. 6.4), drawdown of Hudson Bay ice into a south-westerly expanding calving bay continued. Observations from the

Antarctic glacier indicate that ice flow tends to converge and concentrate discharge into ice streams localized in major sub-ice depressions or channels (Denton and Hughes, 1981a; Doake et al, 1987).

In Hudson Bay, there is some evidence to suggest that major ice streams or, at least, zones of converging ice flow, existed in Hudson Basin and the Winisk Trough and served as a focus for the extension of the calving bay (Fig. 6.5). The zone of mixed provenance (Fig. 5.1), interpreted as the confluence between ice flow from the Keewatin and Nouveau Quebec centres, is coincident with the Hudson Basin and indicates convergent ice flow in the area (Fig. 5.2). Dispersal trends of lithologies and heavy mineral assemblages derived from sources in central Hudson Bay and Quebec coastal areas and northwest-southeast trending flutings and associated corduroy features east of Hudson Basin appear to represent flow into the topographic depression from the Midbay Bank. Similarly, the moraines on either side of the Hudson Basin (Fig. 5.7) suggest stabilization of the ice sheet and a probable temporary margin of the calving bay in central Hudson Bay.

Evidence supporting ice streaming and subsequent formation of a calving bay within the Winisk Trough is more limited. Flow into the depression is suggested by the eastward dispersal of pink carbonate clasts and siderite, derived from outcrops in central Hudson Bay. Onshore, Wyatt (1987) and Thorleifson (1989) have interpreted the youngest till exposed along the Winisk and Severn River valleys as deposits of an ice stream flowing from central Hudson Bay and localized in the Winisk Trough. Similarly, Andrews and Falconer (1969) attribute late southwest trending ice flow indicators on the Ottawa Islands as a re-orientation of ice flow towards a calving bay in the Winisk Trough.

The development of major ice streams in Hudson Bay and the resulting reorientation of ice flow, implies the separation of

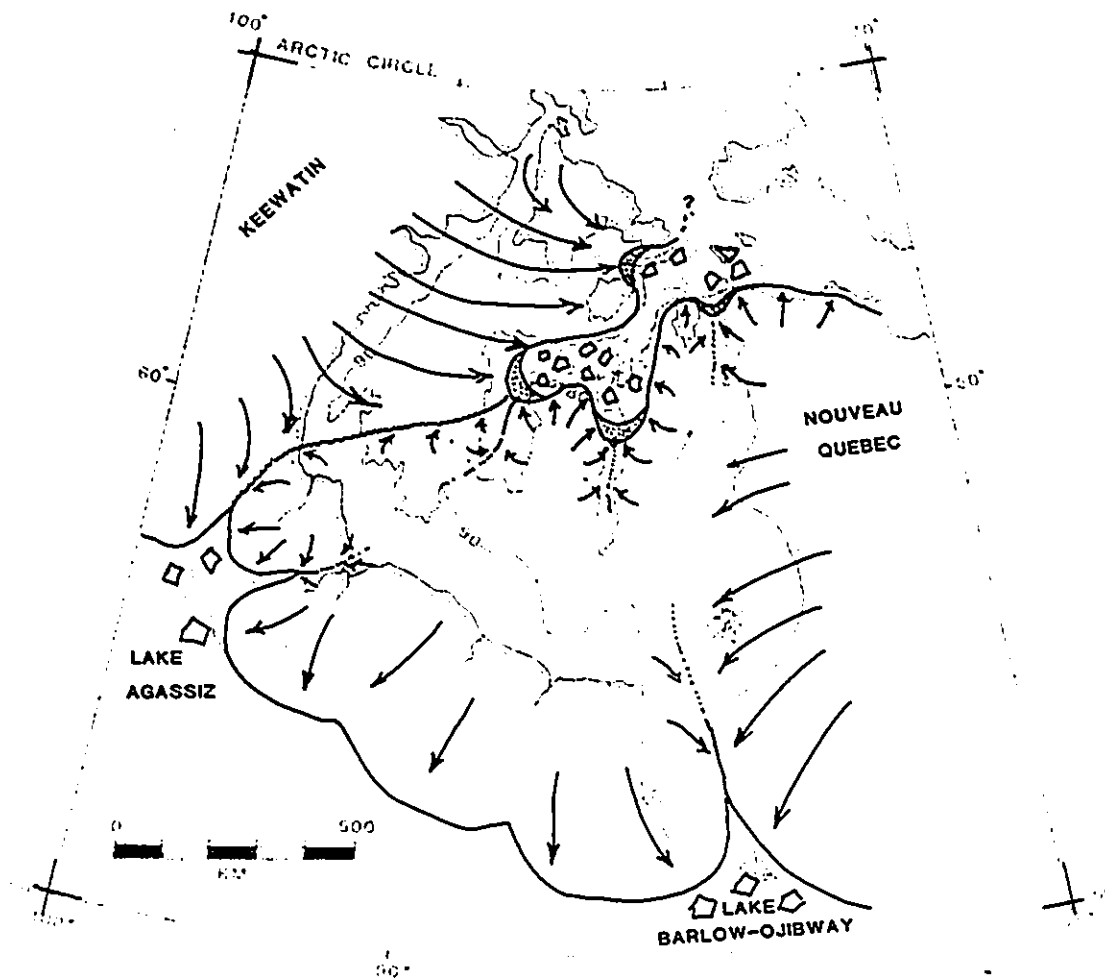


Figure 6.5: Deglaciation Stage 2: Extension of calving bay into Hudson Bay. Formation of proglacial lakes between the southern margin of the ice sheet and major drainage divides. Nouveau Quebec ice remnant becomes isolated in central Hudson Bay.

the ice sheet into lobes. At this stage, the ice mass centred over the Midbay Bank formed an independent ice flow centre (Fig. 6.5). In northern Manitoba, the Leaf Rapids interlobate moraine marks the westward extent of till of eastern provenance and the zone of convergence between ice flow from centres in the District of Keewatin and Nouveau Quebec (Kaszycki and DiLabio, 1986). South of James Bay, convergent ice flow along the Harricana Interlobate moraine marks the boundary between ice flow from centres in Hudson Bay and Nouveau Quebec (Veillette, 1986). These moraines mark the eastern and western extent of an area characterized by a pronounced lobate pattern of overlapping end and interlobate moraines (Fig. 1.7) (Prest et al, 1969).

At this time, extensive proglacial lakes were developing between the retreating ice margin and the major drainage divides south of Hudson Bay: Glacial Lake Agassiz in northern Ontario and Manitoba, and Lake Barlow-Ojibway in Quebec and Ontario (Vincent and Hardy, 1979; Dredge 1983; Klassen, 1983) (Fig. 6.5). Relict scours in large areas of northern Ontario and Manitoba indicate active calving of large icebergs from the glacier margin (Dredge, 1982; Dredge and Cowan, in press). Numerous ice advances into the proglacial lakes in these areas have also been documented (Dredge et al, 1986; Dredge and Cowan, in press) and interpreted as surges of the ice margin resulting from increased water at the glacier sole and, consequently, decreased basal pressures (Denton and Hughes, 1981a; Clayton et al, 1985; Dyke and Prest, 1987; Kaszycki, 1987; Dredge and Cowan, in press).

Stage 3: Catastrophic Drainage of Proglacial Lakes and Incursion of the Tyrrell Sea

Continued southward propagation of the calving bay(s) and ice streaming resulted in general shrinkage of the ice sheet and, eventually, drainage of the proglacial lakes and incursion of the Tyrrell Sea (Fig. 6.6).

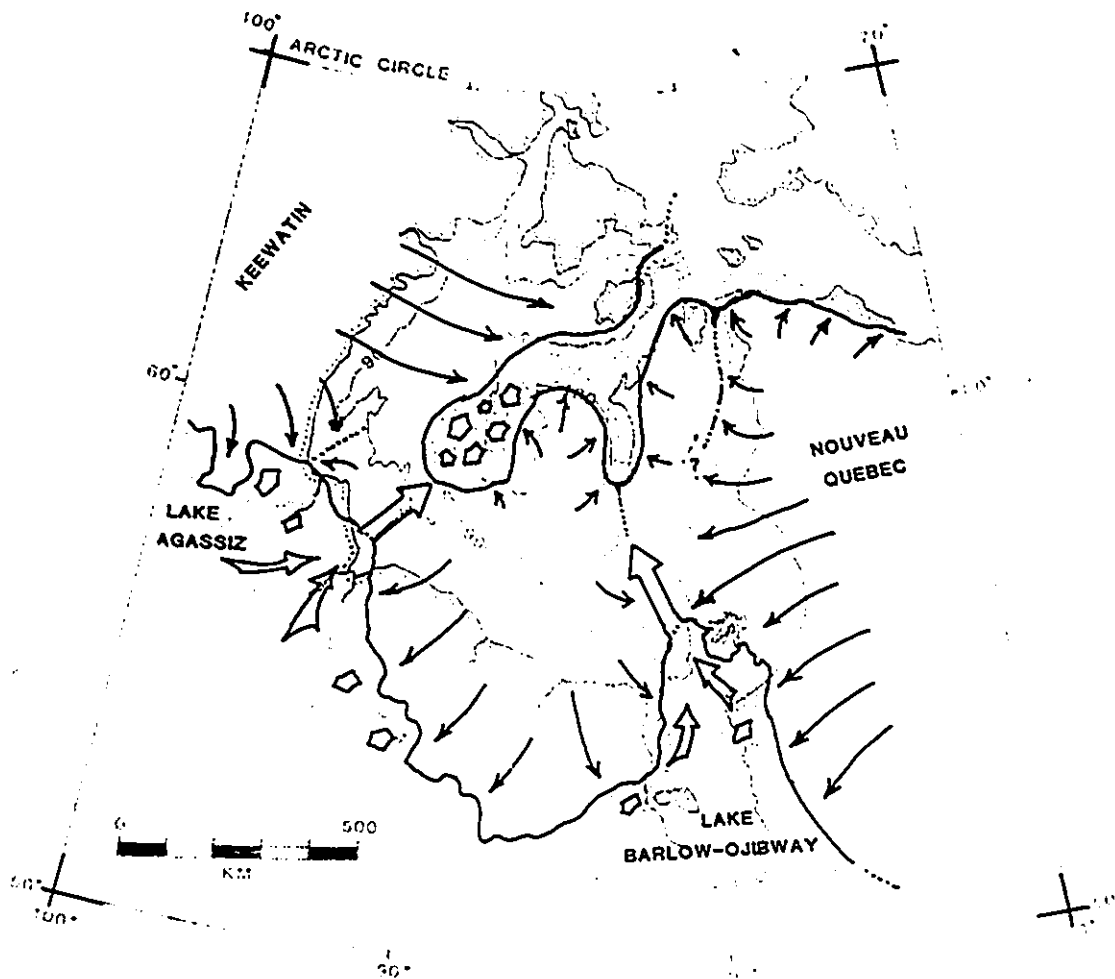


Figure 6.6: Deglaciation Stage 3: Catastrophic drainage of proglacial Lakes Agassiz and Barlow-Ojibway and incursion of Tyrrell Sea. Large arrows indicate possible location of drainage channels.

It is postulated that northward catastrophic drainage of Lake Agassiz was centred offshore from the Nelson River. The interpretation is supported by offshore dispersal trends of siderite (Fig. 4.12), the recognition of sand waves offshore from the mouth of the Nelson River buried by post-glacial sediment and the association of these features with the area of arcuate scour (Fig. 5.7). From onshore observations in Manitoba, Klassen (1983) proposed subglacial drainage of Lake Agassiz into the sea in the Nelson River area. Elson (1967) also suggests final drainage through the Nelson River valley.

Proglacial Lake Barlow/Ojibway occupied the re-entrant between Hudson Bay and Nouveau Quebec ice masses along the Harricana Interlobate moraine (Vincent and Hardy, 1979; Veillette, 1986). Prior to drainage, it extended at least as far north as the Great Whale River area (Vincent and Hardy, 1979) and may have extended well into Hudson Bay west of the Belcher Islands. The lake is thought to have drained to sea level along the northern extension of the interlobate zone (Fig. 6.6), possibly along the Winisk Trough as suggested by Core HU 87-028-041 (Appendix B). This core contains sorted sand and gravel as well as clasts of organic material with a pollen spectra representative of the forest/tundra transition (Mott, 1989). The organic detritus may represent material eroded from deposits in the James Bay Lowlands and transported and deposited in channels (subglacial(?)) during lake drainage (Weertman and Birchfield, 1982).

The drainage of Lake Barlow/Ojibway is interpreted as a catastrophic event and is marked by a regional unconformity and a clay pebble conglomerate consisting of rounded clasts of rhythmically laminated clay and silt enclosed in a clayey matrix (Skinner, 1973; Hardy, 1976, 1982). A similar unit has also been observed in the basal part of the marine sediments of cores collected in the Great Whale River area (Henderson, in press; de

Vernal et al, in press). Drainage of the lake lowered water level approximately 250 m (Hillaire-Marcel and Vincent, 1979).

The timing of drainage of the proglacial lakes and incursion of the Tyrrell Sea is based on the dating of marine deposits onshore. The oldest date in northeastern Manitoba, obtained from shells in beach deposits, is 8530 ± 220 yr BP (GSC-896) (Craig, 1969) and has been regarded as suspect, likely obtained from a mixed population containing old shells (Dyke and Dredge, in press). More recently, however, corroborating dates up to 8200 yr BP have been reported from Nelson River sections (Dredge and Cowan, in press). In the James Bay area, the oldest date on marine shells is 7880 ± 160 yr BP (QU-122) (Hardy, 1982), younger than those of Manitoba. Considering the error associated with age dating and the variation between laboratories, it is possible that the two drainage events were essentially synchronous. The influence of freshwater and/or glacial meltwater associated with proglacial lake drainage is possibly recorded in glaciomarine sediments of Hudson Strait where down-core measurements of oxygen isotope ratios of benthic foraminifera indicate lower salinities just prior to a dated horizon of 8060 ± 70 yr BP (Vilks et al, 1989).

Stage 4: Retreat of Ice Margin to Perimeter of Tyrrell Sea

The drainage of Lakes Agassiz and Barlow/Ojibway and the opening of marine corridors along the eastern and western margin of the bay essentially isolated a large ice mass over central Hudson Bay. This thinning remnant ice eventually lifted off and floated, possibly as a large ice island as suggested by Dredge et al (1986) and Dyke and Prest (1987). Alternatively, it may have broken up into a tightly controlled iceberg mass and formed the parallel to subparallel iceberg scours observed on the seafloor west and northwest of the Hudson Basin. The low and irregular distribution of sediment of central and eastern provenance in the surficial deposits of the northwestern

quadrant of the bay may represent sediment transported and deposited by this ice mass.

In general, however, the lack of mixing of sediment of varied provenance throughout the bay suggests that ice movement during the break-up of the ice sheet covering Hudson Bay was either tightly controlled by the marginal positions of Keewatin and Nouveau Quebec ice or it was debris poor. There is some evidence to suggest that a large proportion of sediment was transported out of the bay by icebergs or floating ice. Josenhans et al (1986) suggest that ice rafted carbonate erratics (20-80%) in marine sediments on the Labrador Shelf are most likely derived from icebergs or floating ice transported from Hudson Bay through Hudson Strait, since other possible limestone sources in the region are limited.

Deglaciation of the bay continued by ice recession to centres in the District of Keewatin and the Ungava Peninsula (Fig. 6.7). The Keewatin ice margin retreated to the western coast, possibly to the position of the large offshore moraines (Fig. 2.8 and Fig. 5.7). Shilts and Aylsworth (1988) propose stagnation and down-wasting of the remnant Keewatin ice sheet on the basis of the zonal distribution of geomorphic features and extensive dendritic esker systems surrounding the Keewatin ice divide (Aylsworth and Shilts, 1985).

Vincent (1977) and Lauriol and Gray (1987) indicate active recession of the Nouveau Quebec ice sheet with calving margins present along the Ungava coast and in the Richmond Gulf area. In northeastern Hudson Bay, the age of deglaciation is estimated at 7000-8000 yr BP for the Ungava coast and 7000-7500 yr BP for the Richmond Gulf area (Lauriol and Gray, 1987). A date of 7430 ± 180 yr BP (GSC-706) was obtained for deglaciation of the Ottawa Islands (Andrews and Falconer, 1969).

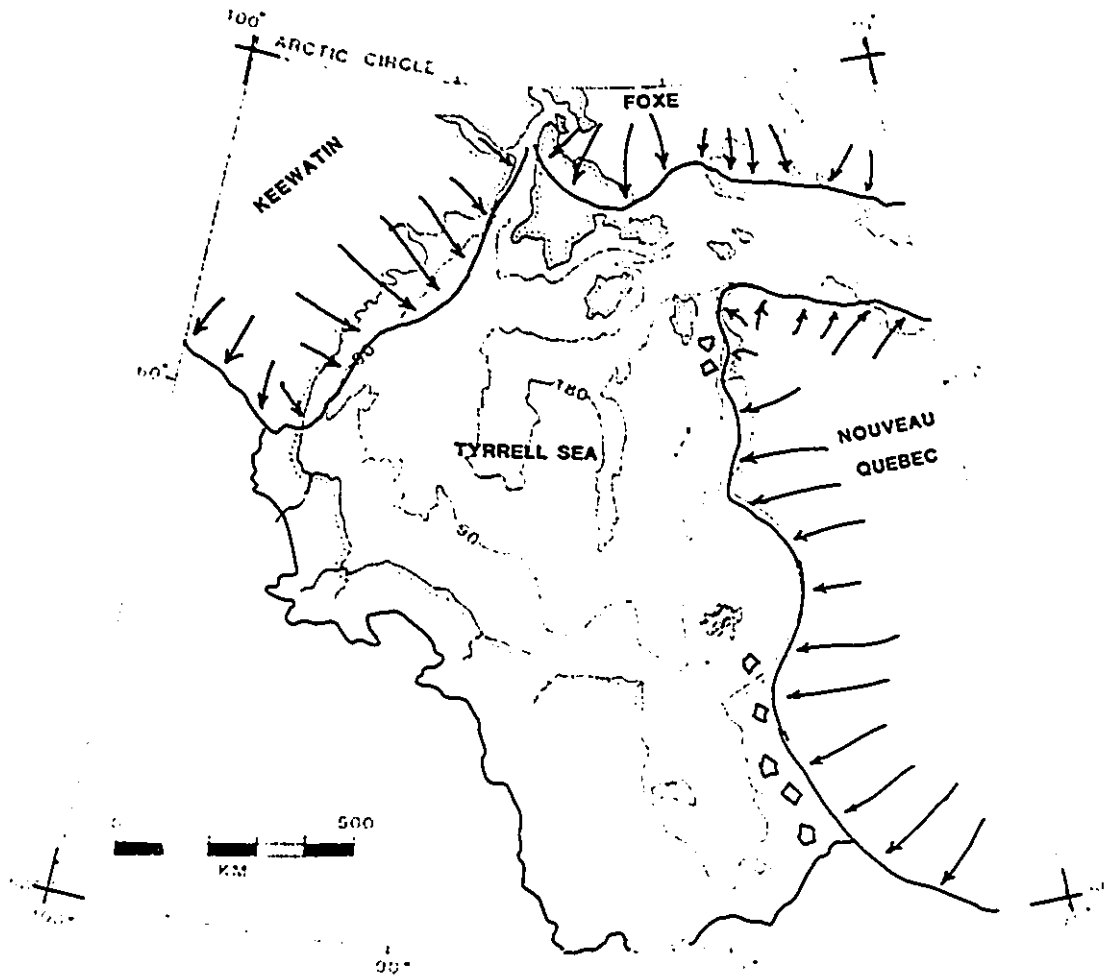


Figure 6.7: Deglaciation Stage 4: Retreat of ice margin to perimeter of Hudson Bay.

6.4. Discussion

There is no evidence to support the model for inception and growth of an ice dome centred over Hudson Bay. Denton and Hughes (1981a) argued that this lack of evidence is related to thermal conditions at the base of the ice sheet during glacial maximum which prevented erosion and, consequently, transport of debris by the glacier. Under these conditions, field observations supporting the single dome hypothesis would be difficult, if not impossible, to find. The available data, particularly flow indicators and dispersal trends of distinctive erratics within and adjacent to the bay, indicate a multi-dome model for glaciation involving ice flow from centres in Keewatin and Nouveau Quebec.

The last regional ice flow across the southern bay and the Hudson Bay Lowlands is indicated by the dispersal of sediment derived from sources in Quebec and eastern Hudson Bay. Younger tills deposited by ice streaming south out of Hudson Bay are more localized and appear to result from changes in the ice sheet profile imposed by the formation of calving bays in northern Hudson Bay. Therefore, sediment dispersal from a centre in Hudson Bay is regarded as a late event post-dating glacial maximum and associated with the deglaciation of the bay.

The present deglaciation model emphasizes the position of calving bays, the locus of the catastrophic drainage of proglacial lakes, and the significance of the residual Hudson Bay ice in Late Wisconsin glacial history. It is postulated that the primary impetus for the break-up of the ice sheet was triggered by the catastrophic drainage of Lakes Agassiz and Barlow/Ojibway to sea-level. In western Hudson Bay, the break-up occurred north of the Nelson River, in the zone of confluence between Keewatin and Nouveau Quebec ice. In eastern Hudson Bay, Lake Barlow/Ojibway drained north of the Harricana Interlobate moraine at the confluence between Nouveau Quebec and residual

Hudson Bay ice. The position of this zone limits the eastward dispersal of sediment derived from sources within the bay.

Deglaciation of Hudson Bay was rapid, as indicated by the lack of sediment on the seafloor. The time of deglaciation is constrained by the oldest date for marine incursion on the Ungava Peninsula (10,400 yr BP; Matthews, 1967) and northeastern Manitoba (8,530 yr BP; Craig, 1969), approximately 2000 years. The present model, however, predicts that ice essentially broke up and cleared Hudson Bay between the drainage of Lakes Agassiz and Barlow Ojibway (8,500-7900 yr BP) and stabilization of the ice sheet on the Keewatin and Ungava coast (8,000-7400 yr BP).

6.5. Further Research

The distribution of distinctive clasts and minerals discussed in this thesis forms an important component in the understanding of glacier flow and ice sheet dynamics in Hudson Bay. As a result, particular areas identified for further detailed study include:

1) Southeastern Hudson Bay and the Richmond Gulf:

Of particular interest is the recognition of the extension of the Harricana Interlobate Moraine into Hudson Bay, the maximum extent of Lake Barlow-Ojibway, and dating of the marine incursion.

2) Offshore from the Nelson and Churchill Rivers:

Recognition of Lake Agassiz sediment and the northern extension of drainage channels observed along the south coast of the bay.

3) Winisk Trough:

Further research is needed to determine the extent and significance of the proposed calving bay in the trough.

4) Northern Hudson Bay and Hudson Strait:

The extent and duration of the ice margin position and the relationship between the Keewatin and Foxe Dome needs to be established, as well as evidence to support ice streaming.

5) Additional coring:

Sub-bottom profiles of several areas of the bay have indicated the presence of up to five possible till sheets. Deep coring in one or several of these areas would further understanding of the glacial stratigraphy and possibly of Wisconsin glacial inception.

6) On land, detailed Quaternary mapping is required on Southampton Island, the Belcher Islands, and the numerous small islands in the Richmond Gulf Embayment.

CHAPTER 7

CONCLUSIONS

Models and reconstructions of the Laurentide Ice Sheet emphasize the importance of Hudson Bay and the surrounding area as the site of Late Wisconsinan glacial inception and deglaciation. Up to the present, however, little was known about the Quaternary deposits underlying the bay. Therefore, the recognition of facies deposited by glacial as opposed to other sedimentary processes, as presented in this thesis, and the distribution of glacially derived sediments and landforms on the seafloor of Hudson Bay provides a unique contribution to the understanding of the glacial history of North America.

Depositional facies are defined by the texture, composition and acoustic character of Hudson Bay surficial deposits. Shipboard observations of the sedimentology and textural variation in cores collected in Hudson Bay suggest that an important factor in distinguishing between glacial and post-glacial sedimentary facies is the proportion of sand and gravel. Few sedimentary processes other than those related to sediment transport by ice (either glacial or sea-ice) can deposit coarse material in the centre of the bay. Processes of sedimentation and sediment modification in the shallow marine environment are most active nearshore and involve the reworking of glacial deposits by rivers and marine currents. The distribution of coarse-grained sediment types within the bay suggests glacial sediments dominate in areas <150m deep, although these deposits are somewhat modified in areas under approximately 100 m depth.

Within the coarse-grained sediments, dispersal trends of distinctive lithologies and mineralogies from known sources adjacent to and underlying the bay appear to be extensions of glacially derived dispersal trains defined onshore. Sediment composition and ice flow indicators suggest the bay was glacial-

iated by ice flow from two opposing and at times overlapping centers: one located in the District of Keewatin and the other in Nouveau Quebec with the shifting zone of confluence localized in the Hudson Basin area and between Coats and Mansel Islands. Eastward and southward dispersal of sediment derived from sources in central Hudson Bay is believed to post-date the extensive glaciation of southern and central Hudson Bay by Nouveau Quebec ice.

Marine geophysical and geological surveys in the bay indicate that the sediment cover is thin, averaging 7-10 m, and consists primarily of till or ice proximal glaciomarine deposits. Post-glacial sedimentation appears to be restricted to areas offshore from major rivers and/or to depressions. Geomorphic features, interpreted from sonographs, are similar to subglacial and ice-marginal landforms observed in areas adjacent to the bay and include glacial flutings, moraines and iceberg scours.

Based on these data, a four-stage model for deglaciation is proposed which invokes (1) the formation of a calving bay in Hudson Strait and stabilization of the ice margin in northern Hudson Bay in the vicinity of Coats and Mansel Islands, (2) southward and southwestward extension of the calving bay into Hudson Bay along regional bathymetric troughs, continued ice sheet thinning through ice streaming and iceberg calving both in the north and south, and isolation of remnant Nouveau Quebec ice over central Hudson Bay, (3) northward drainage of proglacial Lakes Agassiz and Barlow/Ojibway toward calving bay(s) in the Hudson Basin region, offshore from the Nelson River, and the Winisk Trough area, north of James Bay, and incursion of the Tyrrell Sea, and (4) disintegration of central Hudson Bay ice and retreat of other sectors of the ice sheet toward centres in the District of Keewatin and Nouveau Quebec.

REFERENCES

- Adshead, J.D., 1983a. Hudson Bay river sediments and regional glaciation: I. Iron and carbonate dispersal trains southwest of Hudson and James Bays. *Canadian Journal of Earth Sciences*, 20: 290-304.
- _____ 1983b. Hudson Bay river sediments and regional glaciation: II. Comparison of carbonate mineralogy of size fractions for ice movement inference. *Canadian Journal of Earth Sciences*, 20: 305-312.
- _____ 1983c. Hudson Bay river sediments and regional glaciation: III. Implications of mineralogical studies for Wisconsin and earlier ice-flow patterns. *Canadian Journal of Earth Sciences*, 20: 313-321.
- Agterberg, F.P., 1984. Trend Surface Analysis. In: G.L. Gaile and C.J. Willmott (Eds.), *Spatial Statistics and Models*. D. Reidel Publishing Company: 147-171.
- Agterberg, F.P. and Chung, C.F., 1975. A computer program for polynomial trend-surface analysis. *Geological Survey of Canada, Paper 75-21*: 51p.
- Allen, J.R.L., 1979. *Physical Processes of Sedimentation*. Earth Science series, No. 1, George Allen and Unwin (Publishers) Ltd., London: 248p.
- Anderson, J.B., Brake, C., Domack, E., Myers, N., and Wright, R., 1983. Development of a polar glacial-marine sedimentation model from Antarctic Quaternary deposits and glaciological information. In: B.F. Molnia (Ed.), *Glacial-Marine Sedimentation*, Plenum Press, New York, U.S.A.: 233-264.
- Anderson, J.B., Brake, C.F., and Myers, N.C., 1984. Sedimentation of the Ross Sea continental shelf, Antarctica. *Marine Geology*, 57: 295-333.
- Anderson, J.B., Domack, E. and Kurtz, D.D., 1980a. Observations of sediment-laden icebergs in Antarctic waters; implications to glacial erosion and transport. *Journal of Glaciology*, 25: 387-396.
- Anderson, J.B., Kurtz, D.D., Domack, E.W. and Balshaw, K.M., 1980b. Glacial and glacial marine sediments of the Antarctic continental shelf. *Journal of Geology*, 88: 399-414.

- Andrews, J.T., 1987. The Late Wisconsin Glaciation and deglaciation of the Laurentide Ice Sheet. In: Ruddiman, W.F. and Wright, H.E., Jr., (Eds.), North America and adjacent oceans during the last deglaciation. Geological Society of America, Geology of North America, K-3: 13-37.
- Andrews, J.T. and Falconer, G., 1969. Late-glacial and post-glacial history and emergence of the Ottawa Islands, Hudson Bay, N.W.T.: Evidence on the deglaciation of Hudson Bay. Canadian Journal of Earth Sciences, 6: 1263-1276.
- Andrews, J.T. and Mahaffy, M.A.W. 1976. Growth rate of the Laurentide Ice Sheet and sea level lowering (with emphasis on the 115,000BP sea level low). Quaternary Research, 6: 167-183.
- Andrews, J.T. and Miller, G.H. 1979. Glacial Erosion and ice sheet divides, northeastern Laurentide Ice Sheet, on the basis of the distribution of limestone erratics. Geology, 7: 592-596.
- Andrews, J.T., Shilts, W.W. and Miller, G.H. 1983. Multiple deglaciations of the Hudson Bay Lowlands, since deposition of the Missinaibi (last interglacial?) Formation. Quaternary Research, 19: 18-37.
- Arsenault, L., Aylsworth, J.M., Cunningham, C.M., Kettles, I.M. and Shilts, W.W., 1982. Surficial geology Eskimo Point, District of Keewatin. Geological Survey of Canada, Map 8-1980. Scale 1:125 000.
- Arsenault, L., Aylsworth, J.M., Kettles, I.M., and Shilts, W.W., 1981. Surficial geology Kaminak Lake, District of Keewatin. Geological Survey of Canada, Map 7-1979. Scale 1:125 000.
- Aylsworth, J.M., Boydell, A.N., Cunningham, C.M., and Shilts, W.W., 1981a. Surficial geology, Macquoid Lake, District of Keewatin. Geological Survey of Canada, Map 11-1980. Scale 1:125 000.
- Aylsworth, J.M., Cunningham, C.M., and Shilts, W.W., 1981b. Surficial geology, Ferguson Lake, District of Keewatin. Geological Survey of Canada, Map 2-1979. Scale 1:125 000.
- _____ 1981c. Surficial geology, Hyde Lake, District of Keewatin. Geological Survey of Canada, Map 8-1979. Scale 1:125 000.
- Aylsworth, J.M., Kettles, I.M., and Shilts, W.W., 1981d. Surficial geology, Dawson Inlet, District of Keewatin. Geological Survey of Canada, Map 9-1979. Scale 1:125 000.

- Aylsworth, J.M. and Shilts, W.W., 1985. Glacial features of the northwestern Canadian Shield. In: Current Research, Geological Survey of Canada, Paper 85-1B: 375-381.
- _____ 1987a. Surficial Geology, Coats Island, District of Keewatin, Northwest Territories. Geological Survey of Canada, Map 1633A, Scale 1:125 000.
- _____ 1987b. Surficial Geology, Mansel Island, District of Keewatin, Northwest Territories. Geological Survey of Canada, Map 1632A, Scale 1:125 000.
- _____ in press. Surficial Geology of Coats and Mansel Islands, Northwest Territories. Geological Survey of Canada, Paper.
- Baragar, W.R.A., 1974. Volcanic studies in the Cape Smith-Wakeham Bay Belt, New Quebec. In: Current Research, Part A, Geological Survey of Canada, Paper 74-1: 155-157.
- Baragar, W.R.A. and Lamontagne, C.G., 1980. The Circum-Ungava belt in eastern Hudson Bay; the geology of Sleeper Islands and parts of the Ottawa and Belcher Islands. In: Current Research, Part A, Geological Survey of Canada, Paper 80-1A: 89-94.
- Baragar, W.R.A. and Scoates, R.F.J. 1981. The Circum-Superior Belt: a Proterozoic plate margin? In: A. Kroner (Ed.), Precambrian Plate Tectonics. Developments in Precambrian Geology, 4, Elsevier, Amsterdam: 297-330.
- Barber, F.G., 1968. The water of Hudson Bay. In: C.S. Beals (Ed.), Science, History and Hudson Bay, volume 1. Queen's Printer, Ottawa: 287-318.
- Barber, F.G., Grainger, E.H. and Pelletier, B.R., 1981. Hudson Bay sea-floor photographs. Maritime Sediments, 16: 11-34.
- Barnes, P.W., Reimnitz, E., and Fox, D., 1982. Ice rafting of fine-grained sediment, a sorting and transport mechanism, Beaufort Sea, Alaska. Journal of Sedimentary Petrology, 52, (2): 493-502.
- Barnes, P.W. and Reimnitz, E. 1974. Sedimentary processes on Arctic shelves off the northern coast of Alaska. In: J.C. Reed and J.E. Sater (Eds.), The Coast and Shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, Virginia: 439-476.
- Bass, D.W. and Woodworth-Lynas, C., 1988. Iceberg crater marks on the seafloor, Labrador Shelf. Marine Geology, 79: 243-260.

- Bayliss, P., Levinson, A.A. and Klovan, J.L. 1970. Mineralogy of bottom sediments, Hudson Bay, Canada. *Bulletin of Canadian Petroleum Geologists*, 18: 469-473.
- Blake, D.H., 1980. Volcanic rocks of the Paleohelikian Dubawnt Group in the Baker Lake-Angikuni Lake area, District of Keewatin, N.W.T.. Geological Survey of Canada, Bulletin 309, 39p.
- Bell, R., 1885. Observations on the geology, zoology and botany of Hudson's Strait and Bay. Geological and Natural History Survey of Canada, Annual Report, 1: DD 6-20.
- Bell, R.T. 1970. The Hurwitz Group - a prototype for deposition on metastable cratons. In: A.J. Baer (Ed.), Basins and geosynclines in the Canadian Shield. Geological Survey of Canada, Paper 70-40: 159-169.
- Bird, J.B. 1953. The Glaciation of central Keewatin, Northwest Territories, Canada. *American Journal of Science*, 251: 215-230.
- Biscaye, P.E., 1965, Mineralogy and sedimentation of Recent deep-sea clay in the Atlantic Ocean and adjacent seas and oceans. *Geological Society of America Bulletin*, 76: 803-832.
- Bjorlykke, K., Bue, B., and Elverhoi, A., 1978. Quaternary sediments in the northwestern part of the Barents Sea and their relation to the underlying Mesozoic bedrock. *Sedimentology*, 25: 227-246.
- Blatt, H., Middleton, G., and Murray, R., 1980. *Origin of Sedimentary Rocks*, Second Edition. Prentice-Hall Inc., New Jersey, U.S.A.: 782p.
- Boissonneau, A.N., 1966. Glacial history of northeastern Ontario. I The Cochrane-Hearst area. *Canadian Journal of Earth Sciences*, 3: 559-578.
- _____ 1968. Glacial history of northeastern Ontario. II The Timiskaming-Algoma area. *Canadian Journal of Earth Sciences*, 3: 97-109.
- Bostock, H.H. 1969. Precambrian sedimentary rocks of the Hudson Bay Lowlands. In: P.J. Hood (Ed.), *Earth Science Symposium on Hudson Bay*. Geological Survey of Canada, Paper 68-53: 206-214.

- Bostock, H.H., 1971. Geological notes on Aquatuk River map-area, Ontario, with emphasis on the Precambrian rocks. Geological Survey of Canada, Paper 70-42: 57pp.
- Bouchard, M.A. and Martineau, G., 1985. Southeastward ice flow in central Quebec and its paleogeographic significance. Canadian Journal of Earth Sciences, 22: 1536-1541.
- Bouchard, M.A. and Marcotte, C., 1986. Regional glacial dispersal patterns in Ungava, Nouveau-Quebec. In: Current Research, Part B, Geological Survey of Canada, Paper 86-1B: 295-304.
- Boulton, G.S., Baldwin, C.T., Peacock, J.D., McCabe, A.M., Miller, G., Jarvis, J., Horsefield, B., Worsley, P., Eyles, N., Chroston, P.N., Day, T.E., Gibbard, P., Hare, P.E., and von Brunn, V., 1982. A glacio-isostatic facies model and amino acid stratigraphy for late Quaternary events in Spitsbergen and the Arctic. Nature, 298: 437-441.
- Boulton, G.S., Smith, G.D., Jones, A.S. and Newsome, J. 1985. Glacial geology and glaciology of the last mid-latitude ice sheets. Journal of the Geological Society of London, 142: 447-474.
- Bouma, A.H., 1969, Methods for the Study of Sedimentary Structures. Wiley-Interscience, John Wiley and Sons Publishers, New York, U.S.A.: 458p.
- Calvert, S.E. and Price, N.B., 1977. Shallow water, continental margin and lacustrine nodules; distribution and geochemistry. In: G.P. Glasby (Ed), Marine Manganese Deposits. Elsevier Oceanographic Series 15, Elsevier Scientific Publishing Co.: 45-86.
- Campbell, N.J. and Collin, A.E., 1958, The discoloration of Foxe Basin ice. Journal of Fisheries Research Board, Canada, 15, (6): 1175-1188.
- Card, K.D. and Ciesielski, A., 1986. DNAG 1. Subdivision of the Superior Province of the Canadian Shield. Geoscience Canada, 13: 5-13.
- Carroll, D. 1970. Clay minerals: a guide to their x-ray identification. Geological Society of America, Special Paper 126: 80p.
- Carver, R.E.(Ed), 1971. Procedures in Sedimentary Petrology, Wiley Interscience, New York. 653p.

- Cecile, M.P., 1973. Lithofacies analysis of the Proterozoic Thelon Formation, Northwest Territories (including computer analysis of field data). unpublished M.Sc. thesis, Carleton University, Ottawa Ontario, Canada. 197p.
- Chamberlain, T.C., 1895. Glacial phenomena of North America. In: J. Geikie (Ed.), *The Great Ice Age*, D. Appleton and Company, New York: pp.724-775.
- Chandler, F.W., 1984. Metallogenesis of an early Proterozoic foreland sequence, eastern Hudson Bay, Canada. *Journal of the Geological Society of London*, 141: 299-313.
- Clark, P.U., 1985. A note on the glacial geology and post glacial emergence of the Lake Harbour region, Baffin Island, N.W.T.. *Canadian Journal of Earth Sciences*, 22: 1864-1871.
- Clark, D.L. and Hanson, A., 1983. Central Arctic Ocean sediment texture: A key to ice transport mechanisms. In: B.F. Molnia (Ed.), *Glacial-Marine Sedimentation*, Plenum Press, New York: 301-330.
- Clayton, L., Teller, J.T. and Attig, J.W., 1985. Surging of the southwestern part of the Laurentide Ice Sheet. *Boreas*, 14: 235-241.
- Craig, B.G. 1969. Late-glacial and postglacial history of the Hudson Bay region. In: P.J. Hood (Ed.), *Earth Science Symposium on Hudson Bay*. Geological Survey of Canada, Paper 68-53: 63-77.
- Davidson, A., 1969. Precambrian geology, Kaminak Lake map area, District of Keewatin. Geological Survey of Canada Paper 69-51.
- _____ 1970. Eskimo Point and Dawson Inlet map areas (north halves), District of Keewatin, 55E and 55F (north parts). Geological Survey of Canada Paper 70-27.
- _____ 1972. The Churchill Province. In: R.A. Price and R.J.W. Douglas (Eds.), *Variations in Tectonic Styles in Canada*. Geological Association of Canada, Special Paper 11: 381-433.
- de Vernal, A., Bilodeau, G., Goyette, C., (in press). Report on palynology and micropaleontology of Hudson Bay cores HU87-028-001 and HU87-028-069. Geological Survey of Canada, Open File.

- Deer, W.A., Howie, R.A. and Zussman, J., 1966. An introduction to the rock-forming minerals. John Wiley and Sons Inc., New York: 528p.
- Denton, G.H. and Hughes, T.J., 1981a. The Last Great Ice Sheets. John Wiley and Sons, New York, 484 pp.
- _____ 1981b. The Arctic Ice Sheet: an outrageous hypothesis. In: G.H. Denton and T.J. Hughes (Eds.), The Last Great Ice Sheets. John Wiley and Sons, New York: 437-467.
- Dimian, M.V., Gray, R., Stout, J., and Wood, B. 1983. Hudson Bay Basin. In: A.W. Bally (Ed.), Seismic expression of structural styles; a picture and work atlas. American Association of Petroleum Geologists, Studies in Geology Series 15, 2: 2.2.4-1-2.2.4-4.
- Dimroth, E., Baragar, W.R.A., Bergeron, R., and Jackson, G.D. 1970. The filling of the Circum-Ungava geosyncline. In: A.J. Baer (ed.), Symposium on basins and geosynclines of the Canadian Shield. Geological Survey of Canada, Paper 70-40; 45-142.
- Dionne, J.C. 1974. The eastward transport of erratics in James Bay area, Quebec. *Revue de géographie de Montréal*, 28: 453-457.
- Doake, C.S.M., Frolich, R.M., Mantripp, D.R., Smith, A.M. and Vaughan, D.G., 1987. Glaciology studies on Rutford ice stream, Antarctica. *Journal of Geophysical Research*, 92 (B9): 8951-8960.
- Domack, E.W., 1982. Sedimentology of glacial and glacial marine deposits on the George V-Adelie continental shelf, east Antarctica. *Boreas*, 11: 79-97.
- Donaldson, J.A., 1967. Two Proterozoic clastic sequences; a sedimentological comparison. *Proceedings of the Geological Association of Canada*, 18: 33-54.
- _____ 1986. Precambrian Geology. In: I.P. Martini (Ed.), *Canadian Inland Seas. Elsevier Oceanography Series*, 44, Elsevier, Amsterdam: 1-15.
- Dredge, L.A., 1982. Relict ice scour marks and late phases of Lake Agassiz in northernmost Manitoba. *Canadian Journal of Earth Sciences*, 19 (5): 1079-1087.

- Dredge, L.A., 1983. Character and development of northern Lake Agassiz and its relation to Keewatin and Hudsonian ice regimes. In: J.T. Teller and L. Clayton (Eds.), Glacial Lake Agassiz, Geological Association of Canada, Special Paper 26.
- Dredge, L.A. and Cowan, W.R. (in press), Quaternary geology of the southwestern Canadian Shield, In: R.J. Fulton, J.A. Heginbottom and S. Funder (Eds.), Chapter 3, Quaternary Geology of Canada and Greenland. Geological Survey of Canada, Geology of Canada, No.1.
- Dredge, L.A., Nixon, F.M. and Richardson, R.J., 1986. Quaternary geology and geomorphology of northwestern Manitoba. Geological Survey of Canada, Memoir 418: 38p.
- Dredge, L.A. and Nielsen, E., 1985. Glacial and interglacial deposits in the Hudson Bay Lowlands; a summary of sites in Manitoba. In: Current Research, Geological Survey of Canada, Paper 85-1A, 247-257.
- Dreimanis, A. and Vagners, U.J., 1971. Bimodal distribution of rock and mineral fragments in basal tills. In: R.P. Goldthwait (Ed.), Till, A Symposium. Ohio State University Press: 237-250.
- Drewry, D., 1986, Glacial Geologic Processes. Edward Arnold (Publishers) Limited, Baltimore, Maryland: 276p.
- Dyke, A.S. and Dredge, L.A. (in press), Quaternary geology of the northwestern Canadian Shield. In: R.J. Fulton, J.A. Heginbottom and S. Funder (Eds.), Chapter 3, Quaternary Geology of Canada and Greenland. Geological Survey of Canada, Geology of Canada, No.1.
- Dyke, A.S., Dredge, L.A. and Vincent, J.-S., 1982. Configuration and dynamics of the Laurentide Ice Sheet during the Late Wisconsin maximum. *Geographie Physique et Quaternaire*, 36: 5-14.
- Dyke, A.S. and Prest, V.K. 1987. Late Wisconsinan and Holocene history of the Laurentide Ice Sheet. *Geographie physique et Quaternaire*, 41: 237-263.
- Eade, K.E., 1974. Geology of the Kognak River map area, District of Keewatin. Geological Survey of Canada, Memoir 377.
- _____, 1978. Notes on metamorphism in southern District of Keewatin. In: Metamorphism in the Canadian Shield. Geological Survey of Canada, Paper 78-10: 191-194.

- Ellwood, D., 1981. Appmap Users Manual, Geological Survey of Canada, Internal Document.
- Elson, J.A., 1967. Geology of Glacial Lake Agassiz. In: W.J. Mayer-Oakes (Ed.), Life, Land, and Water. Department of Anthropology, University of Manitoba, Occasional Paper 1: 36-95.
- Elverhoi, A. 1984. Glacigenic and associated marine sediments in the Weddell Sea, fjords of Spitsbergen, and the Barents Sea: A Review. *Marine Geology*, 57: 53-88.
- Emery, K.O., 1938. Rapid method of mechanical analysis of sands. *Journal of Sedimentary Petrology*, 8: pp. 105-111.
- 1968. Relict sediments of continental shelves of the world. *American Association of Petroleum Geologists Bulletin*, 52: 445-464.
- Eyles, N., Eyles, C.H., and Miall, A.D., 1983. Lithofacies types and vertical profile models; an alternative approach to the description and environmental interpretation of glacial diamict and diamictite sequences. *Sedimentology*, 30: 393-410.
- Fisher, D.A., Reeh, N., and Langley, K., 1985. Objective reconstructions of the late Wisconsin Laurentide Ice Sheet and the significance of deformable beds. *Geographie Physique et Quaternaire*, 39: 229-238.
- Flint, R.F., 1943. Growth of North American ice sheet during Wisconsin age. *Bulletin of the Geological Society of America*, 54: 325-362.
- Folk, R.L., 1968, *Petrology of Sedimentary Rocks*. Hemphill's Book Store, Austin, Texas: 170p.
- Fraser, J.A., 1983. Geology of Hyde Lake map area, District of Keewatin, N.W.T.. Geological Survey of Canada Paper 82-9.
- Fraser, J.A., Heywood, W.W., and Mazurski, M.A. 1978. Metamorphic map of the Canadian Shield. Geological Survey of Canada, Map 1475A.
- Fulton, R.J. and Prest, V.K., 1987. The Laurentide Ice Sheet and its significance. *Geographie Physique et Quaternaire*, 41(2): 181-186.
- Garrels, R.M., and Christ, C.L., 1965. *Solutions, Minerals, and Equilibria*. Harper, New York: 450p.

- Gibbs, R.J., 1965. Error due to segregation in quantitative clay mineral x-ray diffraction mounting techniques. *American Mineralogist*, 50: 741-751.
- Gibbs, R.J. and Konwar, L. 1982. Effect of pipetting on mineral flocs. *Environmental Science and Technology*, 16: 119-121.
- Gilbert, R., 1983. Sedimentary process of Canadian Arctic fjords. *Sedimentary Geology*, 36: 147-175.
- Goodwin, A.M. 1972. The Superior Province. In: R.A. Price and R.J.W. Douglas (Eds.), *Variations in Tectonic Styles in Canada*. Geological Association of Canada, Special Paper 11: 527-623.
- Grant, A.C. 1969. Some aspects of the bedrock geology of Hudson Bay as interpreted from continuous seismic reflection profiles. In: P.J. Hood (Ed.), *Geological Survey of Canada, Paper 68-53*: 136-143.
- Grant, A.C. and Sanford, B.V., 1988. Bedrock geological mapping and basin studies in the Hudson Bay region. In: *Current Research, Part B, Geological Survey of Canada Paper 88-1B*: 287-296.
- Gray, J.T., de Boutray, B., Hillaire-Marcel, C., and Lauriol, B. 1980. Postglacial emergence of the west coast of Ungava Bay, Quebec. *Arctic and Alpine Research*, 12: 19-30.
- Gray, J.T. and Lauriol, B. 1985. Dynamics of the Late Wisconsin ice sheet in the Ungava Peninsula interpreted from geomorphological evidence. *Arctic and Alpine Research*, 17: 279-310.
- Griffin, J.J., Windom, H., and Goldberg, E.D., 1968. The distribution of clay minerals in the world ocean. *Deep-sea Research*, 15: 433-459
- Griffiths, J.C., 1967. *Scientific Method in Analysis of Samples*. McGraw-Hill Book Company, New York: 508pp.
- Haldorsen, S, 1977. The petrography of till - a study from Ringsaker, southeastern Norway. *Norges Geologiske Undersøelse*, 336: 1-36.
- Hardy, L., 1976. Contribution à l'étude morphologique de la portion québécoise des Basses Terres de la Baie de James. Thèse PhD. McGill University, Montreal. 264p.

- Hardy, L., 1982. Le Wisconsinien supérieur a l'est de la baie James (Québec). *Le Naturaliste Canadien*, 109 (3): 333-351.
- Henderson, P.J. 1983a. A study of the heavy mineral distribution in the bottom sediments of Hudson Bay. In: *Current Research, Geological Survey of Canada, Paper 83-1A*, 347-351.
- _____ 1983b. A study of the heavy mineral distribution in the bottom sediments of Hudson Bay: reply. In: *Current Research, Geological Survey of Canada, Paper 83-1B*: 435-436.
- _____ 1985. Dispersal patterns of specific heavy mineral species and granule compositions in Hudson Bay sediments (Abst). In: *Arctic Land-Sea Interaction, Abstracts. 14th Arctic Workshop*: 194-195.
- _____ (in press). Data report: description and composition of cores and grab samples, HU-87-028, Hudson Bay. *Geological Survey of Canada, Open File*.
- Henderson, P.J. and Josenhans, H., 1987. Glacigenic and marine sedimentation in Hudson Bay, Canada (Abst.). In: *Programme with Abstracts. International Union for Quaternary Research, XII International Congress, National Research Council of Canada, Ottawa*: p.185.
- Henderson, P.J., Kaszycki, C.A., Klassen, R.A., Shilts, W.W., Thorleifson, L.H., 1987. Drift composition and glacial ice flow patterns beneath the central portion of the Laurentide Ice Sheet (Abst.). In: *Programme with Abstracts. International Union for Quaternary Research, XII International Congress, National Research Council of Canada, Ottawa*: p.185.
- Herd, R.K. 1978. Notes on metamorphism in New Quebec. In: J.A. Fraser and W.W. Heywood (Eds.), *Metamorphism in the Canadian Shield. Geological Survey of Canada, Paper 66-40*, 20p.
- Heywood, W.W., 1973. Geology of Tavani map-area, District of Keewatin. *Geological Survey of Canada, Paper 72-47*.
- Heywood, W.W. and Sanford, B.V. 1976. Geology of Southampton, Coats and Mansel Islands, District of Keewatin, Northwest Territories, *Geological Survey of Canada, Memoir 382*: 35p.
- Higgins, P.J., 1982. Procedure for clay separations. *Terrain Science Division, Geological Survey of Canada, Internal Report*: 2p.

- Hillaire-Marcel, C. 1976. La déglaciation et le relèvement isostatique sur la côte est de la baie d'Hudson. Cahiers de géographie de Québec, 20: 185-220.
- Hillaire-Marcel, C. and Occhietti, S., 1980. Chronology, paleogeography and paleoclimatic significance of the late and post-glacial events in eastern Canada. Zeitschrift fur geomorphologie, 24: 373-392.
- Hillaire-Marcel, C. and Vincent, J.-S., 1980. Holocene stratigraphy and sea level changes in southeastern Hudson Bay, Canada. Paleo-Quebec, 11, 165pp.
- Holdsworth, G., 1978. Some mechanisms for the calving of icebergs. In A.A. Hussein (Ed.), Iceberg Utilization. Pergamon Press, Oxford: 160-175.
- Holdsworth, G. and Glynn, J.E., 1981. A mechanism for the formation of large icebergs. Journal of Geophysical Research, 86(C4): 3210-3222.
- Hubert, J.F., 1971. Analysis of heavy-mineral assemblages. In: R.E. Carver (Ed.), Procedures in Sedimentary Petrology. Wiley Interscience, New York: 453-478.
- Hughes, T., Denton, G.H. and Grosswald, M.G., 1977. Was there a late-Wurm Arctic Ice Sheet? Nature, 266: 596-602.
- Hughes, T.J., Denton, G.H., and Fastook, J.L., 1985. The Antarctic ice sheet; an analogy for Northern Hemisphere paleo ice sheets. In: Woldenberg, M.J. (Ed.), Models in Geomorphology. Allen and Unwin, London: 25-72.
- Hutchins, R.W., McKeown, D.L. and King, L.H., 1976. A deep tow high resolution seismic system for continental shelf mapping. Geoscience Canada, 3: 95-100.
- Inman, D.L., 1952, Measures for describing the size distribution of sediments. Journal of Sedimentary Petrology, 22: 125-145.
- Ives, J.D., Andrews, J.T. and Barry, R.C., 1975. Growth and decay of the Laurentide Ice Sheet and comparisons with Fenno-Scandinavia. Naturwissenschaften, 62: 118-125.
- Jackson, G.D. 1960. Belcher Islands, Northwest Territories. Geological Survey of Canada, Paper 60-20: 13pp.
- Josenhans, H.W., Zevenhuizen, J., and Klassen, R.A., 1986. The Quaternary geology of the Labrador Shelf. Canadian Journal of Earth Sciences, 23: 1190-1213.

- Josenhans, H.W., Balzer, S., Henderson, P.J., Nielsen, E., Thorliefson, H.L., and Zevenhuisen, J., 1988. The Quaternary sediments of Hudson Bay; based on preliminary seismostratigraphic and geomorphic interpretations. In: Current Research, Geological Survey of Canada, Paper 88-1B: 271-286.
- Josenhans, H.W. and Zevenhuisen, J., 1988. A comparison of offshore and onshore glacial and postglacial geomorphology of Hudson Bay region and its implications for the mechanism of late breakup of the Laurentide Ice Sheet (Abstr.). 17th Annual Arctic Workshop. INSTAAR, University of Colorado, Boulder, Colorado; 28.
- Kaszycki, C.A., 1987. Glacial geomorphology of the southern Canadian Shield. In: W.L. Graf (Ed.), Geomorphic systems of North America. Geological Society of America, Centennial Special Volume 2: 150-155.
- Kaszycki, C.A. and Dilabio, R., 1986. Surficial geology and till geochemistry, Lynn Lake-Leaf Rapids region, Manitoba. In: Current Research, Part B, Geological Survey of Canada, Paper 86-1B: 245-256.
- Kaszycki, C.A. and Shilts, W.W., 1979. Average depth of glacial erosion, Canadian Shield. In: Current Research, Part B, Geological Survey of Canada, Paper 79-1B: 395-396.
- _____ 1980. Glacial erosion of the Canadian Shield - calculation of average depths. Atomic Energy of Canada Ltd., Technical Record 106, 43p.
- Kelling, G., Sheng, H., and Stanley, D., 1975: Mineralogic composition of sand-sized sediment on the outer margin off the mid-Atlantic states: assessment of the influence of the ancestral Hudson and other fluvial systems. Geological Society of America Bulletin, 86: 853-862.
- King, L.H. and Fader, G.B.J., 1986. Wisconsinan glaciation of the Atlantic continental shelf of southeast Canada. Geological Survey of Canada, Bulletin 363, 72p.
- Klassen, R.A., 1987. Glacial geomorphology of Labrador and eastern Quebec. In: W.L. Graf (Ed.), Geomorphic systems of North America. Geological Society of America, Centennial Special Volume 2: 142-150.
- Klassen, R.A. and Bolduc, A. 1984. Ice flow directions and drift composition, Churchill Falls, Labrador. In: Current Research, Part A, Geological Survey of Canada, Paper 84-1A, 255-258.

- Klassen, R.W., 1983. Lake Agassiz and the glacial history of northern Manitoba. In: Teller, J.T. and Clayton, L. (Eds.), Glacial Lake Agassiz. Geological Association of Canada, Special Paper, 26: 97-115.
- Kranck, K., 1973, Flocculation of suspended sediment in the sea. *Nature*, 246: pp. 348-350.
- Kravitz, J.H. 1976. Textural and mineralogical characteristics of the surficial sediments of Kane Basin. *Journal of Sedimentary Petrology*, 46,3: pp. 710-725.
- _____ 1982. Sediments and sediment processes in Kane Basin, a high Arctic glacial marine basin. Institute of Arctic and Alpine Research, Occasional Paper 39: 184p.
- _____ 1983. Glacial and glacial-marine lithofacies of the Kane Basin. In: B.F. Molnia (Ed.), *Glacial-Marine Sedimentation*, Plenum Press, New York: 401-450.
- Kretz, R. 1960. Geological observations in northern New Quebec. Geological Survey of Canada, Paper 60-12: 17p.
- Krumbein, W.C. and Pettijohn, F.J., 1938. *Manual of Sedimentary Petrology*. Appleton-Century-Crofts, Inc., New York: 549p.
- Larnder, M.M. 1968. The ice of Hudson Bay. In: C.S. Beals (Ed.), *Science History and Hudson Bay*, volume 1. Queen's Printer, Ottawa: 318-341.
- Lauriol, B. and Gray, J.T. 1987. The decay and disappearance of the late Wisconsin ice sheet in the Ungava Peninsula, Northern Quebec, Canada. *Arctic and Alpine Research*, 19: 109-126.
- LeCheminant, A.N., Jackson, M.J., Galley, A.G., Smith, S.L. and Donaldson, J.A., 1984. Early Proterozoic Amer Group, Beverly Lake map area, District of Keewatin. In: *Current Research, Part B*, Geological Survey of Canada, Paper 84-1B: 159-172.
- Lee, H.A., 1959a. Eastward transport of glacial erratics from Hudson Bay. *Bulletin of the Geological Society of America*, 70: 219-222.
- _____ 1959b. Surficial geology of southern District of Keewatin and the Keewatin ice divide, Northwest Territories. Geological Survey of Canada, Bulletin 51.

- Lee, H.A., 1960. Late glacial and post-glacial Hudson Bay sea episode. *Science*, 131: 1609-1611.
- _____ 1968. Quaternary Geology. In: C.S. Beals (Ed.), *Science, History and Hudson Bay*, Volume 2. Queen's Printer, Ottawa: 503-543.
- Lee, H.A., Craig, B.G. and Fyles, J.G., 1957. Keewatin Ice Divide, (Abstr.), *Geological Society of America Bulletin*, 68: 1760-1761.
- Leslie, R.J. 1963. Foraminiferal study of a cross-section of Hudson Bay, Canada. *Geological Survey of Canada*, Paper 63-16: 25p.
- _____ 1964. Sedimentology of Hudson Bay, District of Keewatin. *Geological Survey of Canada*, Paper 63-48, 31p.
- _____ 1965. Ecology and paleoecology of Hudson Bay foraminifera. *Bedford Institute of Oceanography Report* 65-6: 192p.
- Leslie, R.J. and Pelletier, B.R. 1965. Bedrock geology in Hudson Bay as interpreted from submarine physiography. *Bedford Institute of Oceanography*, Report 65-12, 18p.
- Levinson, A.A., 1974. *Introduction to Exploration Geochemistry*. Applied Publishing Limited, Wilmette, Illinois: 614p.
- Lewis, C.F.M. and Sanford, B.V. 1971. Marine activities in Hudson Bay, 1971. In: *Report of Activities, Part A*. *Geological Survey of Canada*, Paper 72-1: 168-169.
- Linden, A., 1975. Till petrographical studies in an Archaean bedrock area in southern central Sweden. *Striae*, 1: 1-57.
- Low, A.P., 1900. Report on an exploration of the east coast of Hudson Bay from Cape Wolstenholme to the south end of James Bay. *Geological Survey of Canada*, 13: 1D-84D.
- _____ 1906. Report on the Dominion Government expedition to Hudson Bay and the Arctic Islands on board the D.G.S. NEPTUNE, 1903-1904. The Queen's Printer, Ottawa, 355pp.
- MacLean, B., Williams, G.L., Sanford, B.V., Klassen, R.A., Blakeney, C. and Jennings, A., 1986. A reconnaissance study of the bedrock and surficial geology of Hudson Strait, N.W.T. In: *Current Research, Part B*. *Geological Survey of Canada*, Paper 86-1B: 617-635.

- Markam, W.E., 1986. The Ice Cover. In: I.P. Martini (Ed.), Canadian Inland Seas. Elsevier Oceanography Series 44, Elsevier, Amsterdam: 101-116.
- Martini, P.I., 1986. Coastal features of Canadian inland seas. In: P.I. Martini (Ed.), Canadian Inland Seas. Elsevier Oceanography Series, 44, Elsevier Science Publisher, New York: 117-142.
- Matthews, B., 1967. Late Quaternary land emergence in northern Ungava, Quebec. *Arctic*, 20: 176-202.
- Maxwell, J.B., 1986. A climatic overview of the Canadian inland seas. In: I.P. Martini (Ed.), Canadian Inland Seas. Elsevier Oceanography Series, 44, Elsevier Science Publisher, New York: 79-100.
- Mayewski, P.A., Denton, G.H. and Hughes, T.J., 1981. Late Wisconsin ice sheets of North America. In: G.H. Denton and T.J. Hughes (Eds.), *The Last Great Ice Sheets*. John Wiley and Sons, New York: 67-178.
- McCave, I.N., 1985. Recent shelf clastic sediments. In: P.J. Brenchley and B.P.J. Williams (Eds.), *Sedimentology - Recent Developments and Applied Aspects*. The Geological Society, Blackwell Scientific Publications, London: 49-65.
- McDonald, B.C., 1969. Glacial and interglacial stratigraphy, Hudson Bay Lowland. In: P.J. Hood (Ed.), *Earth science symposium on Hudson Bay*. Geological Survey of Canada, Paper 68-53: 78-99.
- McDonald, B.C. and Kelly, R.G., 1968. Procedures used in sedimentology laboratory, Geological Survey of Canada, Ottawa. Limited Circulation Report, 18pp.
- Mitchum, Jr., R.M., Vail, P.R., and Sangree, J.B., 1977. Stratigraphic interpretation of seismic reflection patterns in depositional sequences. In: C.E. Payton (Ed.), *Seismic Stratigraphy-applications to hydrocarbon exploration*. American Association of Petroleum Geologists, Memoir 26: 117-134.
- Molnia, B.F., 1983, Subarctic glacial-marine sedimentation. In: B.F. Molnia (Ed.), *Glacial-Marine Sedimentation*, Plenum Press, New York: 95-144.
- Mott, R.J., 1989. Palynological Report 89-5. Quaternary Paleocology Laboratory, Geological Survey of Canada.

- Naidu, A.S., Burrell, D.C., and Hood, D.W., 1971. Clay mineral composition and geologic significance of some Beaufort sea sediments. *Journal of Sedimentary Petrology*, 41 (3): 691-694.
- Nelson, C.H., 1982. Modern shallow water graded sand layers from storm surges, Bering Shelf: a mimic of Bouma sequences and turbidite systems. *Journal of Sedimentary Petrology*, 52: 537-545.
- Nelson, S.J. 1968. Geological interpretations of Hudson Bay, Aquitaine Company of Canada, Internal Report: 257pp.
- Netterville, J., 1974. Quaternary stratigraphy of the lower God's River region, Hudson Bay Lowlands, Manitoba. M.Sc. thesis, Univ. Calgary, Alberta, 79p.
- Nielsen, E., Morgan, A.V., Morgan, A., Mott, R.J., Rutter, N.W., and Causse, C., 1986. Stratigraphy, paleoecology, and glacial history of the Gillam area, Manitoba. *Canadian Journal of Earth Sciences*, 23: 1641-1661.
- Norris, A.W. 1986. Review of Hudson platform Paleozoic stratigraphy and biostratigraphy. In I.P. Martini (Ed.), *Canadian Inland Seas, Elsevier Oceanography Series*, 44: 17-42.
- Norris, A.W. and Sanford, B.V. 1969. Paleozoic and Mesozoic geology of the Hudson Bay Lowlands. In: P.J. Hood (Ed.), *Earth Science Symposium on Hudson Bay, Geological Survey of Canada, Paper 68-53: 169-205.*
- Nuorteva, J., 1988. The study of Quaternary marine deposits by acoustic methods. *Geological Survey of Finland, Report of Investigation 82: 32p.*
- Paré, D.G., 1982. Application of heavy mineral analysis to problems of till provenance along a transect from Longlac, Ontario to Somerset Island. M.Sc. thesis (unpublished), Carleton University, Ottawa: 76p.
- Pelletier, B.R. 1966. Bathymetry and geology of Hudson Bay and approaches. In: R. Fairbridge (Ed.), *Encyclopedia of Earth Sciences*. Rheinhold Publishing Company, 1: 359-363.
- _____ 1969. Submarine physiography, bottom sediments, and models of sediment transport in Hudson Bay. In: P.J. Hood (Editor), *Earth Science Symposium on Hudson Bay, Geological Survey of Canada, Paper 68-53: 100-135.*

- Pelletier, B.R., 1986. Seafloor morphology and sediments. In: I.P. Martini (Ed.), Canadian Inland Seas, Elsevier Oceanography Series, 44. Elsevier Science Publishers, New York: 143-162.
- Pelletier, B.R., Wagner, F.J.E. and Grant, A.C., 1968. Marine Geology. In: C.A. Beales (Ed.), Science, History and Hudson Bay. Canadian Department of Energy, Mines and Resources, 2: 557-613.
- Pettijohn, F.J., 1957. Sedimentary Rocks. Harper and Brothers, New York: 718p.
- Poppe, L.J., Commeau, R.F., Commeau, J.A., Manheim, F.T., Aruscavage, P.J., 1984. Ferromanganese micronodules in the surficial sediment of Georges Bank. Journal of Marine Research, 42: 463-472.
- Praeg, D.B., MacLean, B., Hardy, I., and Mudie, P.J., 1986. Quaternary geology of the southeast Baffin Island continental shelf. Geological Survey of Canada, Paper 85-14, 38p.
- Prest, V.K. 1969. Retreat of Wisconsin and Recent ice in North America. Geological Survey of Canada, Map 1257A. 1: 5,000,000 scale .
- _____ 1970. Quaternary Geology of Canada. In: R.J.W. Douglas (Ed.), Geology and Economic Minerals of Canada. Geological Survey of Canada, Economic Geology Series No. 1, 5th Edition: 675-764.
- _____ 1983. Canada's Heritage of Glacial Features, Geological Survey of Canada, Miscellaneous Report 28: 119p.
- _____ 1984. The Late Wisconsin glacier complex, In: R.J. Fulton (Ed.), Quaternary stratigraphy of Canada; a Canadian contribution to IGCP Project 24. Geological Survey of Canada, Paper 84-10: 21-38, Map 1584A (in pocket).
- Prest, V.K., Grant, D.R., and Rampton, V.N., 1967. Glacial map of Canada, Geological Survey of Canada, Map 1253A, 1: 5,000,000 scale.
- Prest, V.K. and Nielsen, E., 1987. The Laurentide Ice Sheet and long-distance transport. INQUA Till Symposium, Geological Survey of Finland, Espoo, 15, Finland, SF 02150.
- Prinsenbergh, S.J., 1986. The circulation pattern and current structure of Hudson Bay. In: I.P. Martini (Ed.), Canadian Inland Seas. Elsevier Oceanography Series 44, Elsevier, Amsterdam: 187-216.

- Prinsenberg, S.J. and Freeman, N.G. 1986. Tidal heights and currents in Hudson Bay and James Bay. In: I.P. Martini (Ed), Canadian Inland Seas. Elsevier Oceanography Series 44, Elsevier, Amsterdam: 205-216.
- Reimnitz, E. and Barnes, R.W., 1974. Sea ice was a geologic agent on the Beaufort Sea Shelf of Alaska. In: J.C. Reed and J.E. Sater (Eds.), The coast and shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, Virginia: 301-353.
- Rencz, A.N. and Shilts, W.W., 1980. Nickel in soils and vegetation of glaciated terrains. In: J.O. Nriagu (Ed.), Nickel in the Environment. John Wiley and Sons, Inc: 151-188.
- Ricketts, B.D. and Donaldson, J.A. 1981. Sedimentary history of the Belcher Group of Hudson Bay. In: F.H.A. Campbell (Ed.), Proterozoic Basins of Canada. Geological Survey of Canada, Paper 81-10: 235-254.
- Rise, L. and Rokoengen, K., 1984. Surficial sediments in the Norwegian sector of the North Sea between 60°30' and 62°N. Marine Geology, 58: 287-317.
- Robe R.Q., 1980. Iceberg drift and deterioration. In: S.C. Colbeck (Ed.), Dynamics of Snow and Ice. Academic Press, New York: 211-260.
- Robin, G. de Q., 1979. Formation, flow and disintegration of ice shelves. Journal of Glaciology, 24 (90): 259-271.
- Rosen, P.S., 1979, Boulder barricades in central Labrador. Journal of Sedimentary Petrology, 49: 1113-1124.
- Sanford, B.V., Grant, A.C., Wade, J.A., and Barss, M.S. 1979. Geology of eastern Canada and adjacent areas. Geological Survey of Canada, Map 1401A, (4 sheets). 1:2,000,000 scale.
- Sanford, B.V. and Norris, A.V., 1975. Devonian stratigraphy of the Hudson Platform, Part I-Stratigraphy and economic geology; Part II-Outcrop and subsurface sections. Geological Survey of Canada, Memoir 379, 372p.
- Sanford, B.V., Norris, A.W. and Bostock, H.H. 1968. Geology of the Hudson Bay Lowlands (Operation Winisk), Geological Survey of Canada, Paper 67-60. 45p.
- Schau, M., 1983. Trace element content of till and gossanous mud in the Baker Lake region, District of Keewatin. In: Current Research, Part A. Geological Survey of Canada, Paper 83-1A: 37-41.

- Schledewitz, D.C.P., 1986. Geology of the Cochrane and Seal Rivers Area. Manitoba Energy and Mines, Geological Report GR80-9.
- Schlee, J., Uchupi, E., and Trumbull, J.V.A., 1965. Statistical parameters of Cape Cod beach and eolian sands. U.S. Geological Survey, Professional Paper 501-D: 118-122.
- Shepard, F.P., 1932. Sediments on the continental shelves. Geological Society of America Bulletin, 43: 1017-1039.
- Shilts, W.W., 1973. Glacial dispersal of rocks, minerals and trace elements in Wisconsinan till, southeastern Quebec, Canada. In: R.F. Black, R.P. Goldthwait, and H. B. Willman (Eds.), Geological Society of America, Memoir 136: 189-219.
- _____ 1976. Glacial till and mineral exploration. In: R.F. Legget, (Ed.), Glacial Till, an Interdisciplinary Study. Royal Society of Canada, Special Publication No. 12, Ottawa: 205-224.
- _____ 1980a. Flow patterns in the central North American ice sheet. Nature, 286: 213-218.
- _____ 1980b. Geochemical profile of till from Longlac, Ontario to Somerset Island. The Canadian Mining and Metallurgical Bulletin, 73: 85-94.
- _____ 1982. Quaternary evolution of the Hudson/James Bay region. Le Naturaliste Canadien, 109: 309-332.
- _____ 1985. Geological models for the configuration, history and style of disintegration of the Laurentide Ice Sheet. In: M.J. Woldenberg (Ed.), Models in Geomorphology, The "Binghamton" Symposia in Geomorphology. International Series 14, George Allen and Unwin, London: 73-91.
- _____ 1986. Glaciation of the Hudson Bay region. In: I.P. Martini (Ed.), Canadian Inland Seas. Elsevier Oceanography Series 44, Elsevier Science Publishers, Amsterdam: 55-78.
- Shilts, W.W. and Aylsworth, J.M., 1987. Glacial geomorphology of northwestern Canadian Shield. In: W.L. Graf (Ed.), Geomorphic systems of North America. Geological Society of America, Centennial Special Volume 2: 126-142.
- Shilts, W.W., Cunningham, C.M. and Kaszycki, C.A., 1979. Keewatin ice sheet - re-evaluation of the traditional concept of the Laurentide Ice Sheet. Geology, 7: 537-541.

- Skinner, R.G., 1973. Quaternary stratigraphy of the Moose River basin, Ontario. Geological Survey of Canada, Bulletin 225, 77p.
- Speidel, D.H. and Agnew, A.F., 1982. The Natural Geochemistry of Our Environment. Westview Press, Boulder, Colorado: 214p.
- Stevenson, I.M., 1968. A geological reconnaissance of Leaf River Map-Area, New Quebec and Northwest Territories. Geological Survey of Canada, Memoir 356, 112p.
- Stuiver, M., Heusser, C.J., and Yang, I.C., 1978. North American glacial history extended to 75,000 years ago. Science, 200: 16-21.
- Sugden, D.E. 1977. Reconstruction of the morphology, dynamics and thermal characteristics of the Laurentide Ice Sheet at its maximum. Arctic and Alpine Research, 9: 21-47.
- Swift, D.J.P., 1970. Quaternary shelves and the return to grade. Marine Geology, 8: 5-30.
- Swift, D.J.P., Stanley, D.J., and Curray, J.R., 1971, Relict sediments on continental shelves: a reconsideration. Journal of Geology, 79: pp. 322-346.
- Taylor, F.C. 1982. Reconnaissance geology of a part of the Precambrian Shield, northern Quebec and Northwest Territories. Geological Survey of Canada Memoir 399: 32p.
- Taylor, R.S., 1956. Glacial geology of north-central Keewatin, Northwest Territories, Canada. Bulletin of the Geological Society of America, 67: 943-956.
- Tella, S., Annesley, I.R., Borradaile, G.J., and Henderson, J.R., 1986. Precambrian geology of parts of Tavani, Marble Island, and Chesterfield Inlet map areas, District of Keewatin: a progress report. Geological Survey of Canada Paper 86-13: 20p.
- Terasmae, J. and Hughes, O.L., 1960. A palynological and geological study of Pleistocene deposits in the James Bay Lowlands, Ontario. Geological Survey of Canada, Bulletin 62: 15p.
- Thomas, R.H., 1979a. Ice Shelves: A Review. Journal of Glaciology, 24: 273-286.
- _____ 1979b. The dynamics of marine ice sheets. Journal of Glaciology, 24: 167-177.

- Thorleifson, L.H., 1989. Quaternary stratigraphy of the central Hudson Bay Lowland, Northern Ontario, Canada. Ph.D. thesis, University of Colorado, Boulder, Colorado: 363p.
- Thorleifson, L.H. and Wyatt, P.H., 1987. Quaternary stratigraphy of the central Hudson Bay Lowland, Northern Ontario (Abst.). In: International Union for Quaternary Research, XII International Congress, Programme with Abstracts: 277.
- Tyrrell, J.B., 1898. The glaciation of north central Canada, *Journal of Geology*, 6: 147-160.
- _____ 1914. The Patrician Glacier south of Hudson Bay. XII International Geological Congress (1913), Ottawa: 523-534.
- _____ 1935. Discovery of Patrician centre of ice dispersion. In: Patrician Center of Glaciation: A Symposium. *Pan-American Geologist*, volume 63, no. 1: 1-5.
- Van der Plas, L. and Tobi, A.C., 1965. A chart for judging the reliability of point counting results. *American Journal of Science*, 263: 87-90.
- Vail, P.R., Todd, R.G. and Sangree, J.B., 1977. Chronostratigraphic significance of seismic reflections. In: C.E. Payton (Ed.), *Seismic Stratigraphy-applications to hydrocarbon exploration*. American Association of Petroleum Geologists, Memoir 26: 99-116.
- Veillette, J.J. 1983. Déglaciation de la vallée supérieure de l'Outaouais, le lac Barlow et le sud du lac Ojibway, Québec. *Géographie physique et Quaternaire*, 37: 67-84.
- _____ 1986. Former southwesterly ice flows in Abitibi-Temiscamingue: implications for the configuration of the Late Wisconsinan ice sheet. *Canadian Journal of Earth Sciences*, 23: 1724-1741.
- Vilks, G., MacLean, B., Deonarine, B., Currie, C.G., and Moran, K., 1989. Late Quaternary Paleoceanography and sedimentary environments in Hudson Strait (Abstr.). Geological Survey of Canada, Current Activities Forum (unpublished).
- Vincent, J.-S., 1977. Le Quaternaire récent de la région du cours inférieur de La Grande Rivière, Québec. Commission Géologique du Canada, Etude 76019: 20p.

- Vincent, J.-S., (in press). Quaternary geology of the south eastern Shield. In: R.J. Fulton, J.A. Heginbottom and S. Funder (Eds.), Chapter 3, Quaternary Geology of Canada and Greenland. Geological Survey of Canada, Geology of Canada, No.1.
- Vincent, J.-S. and Hardy, L., 1979. The evolution of late post-Algonquin glacial lake phases in Ontario and glacial lakes Barlow and Ojibway, Quebec. Geological Survey of Canada, Bulletin 316: 18p.
- Vorren, T.O., Hald, M., Edvardsen, M., Lind-Hansen, O., 1983. Glacigenic sediments and sedimentary environments on continental shelves; General principles with a case study from the Norwegian shelf. In: J. Ehlers (Ed.), Glacial Deposits in North-west Europe. A.A. Balkema Publishers, Netherlands: 61-73.
- Walker, R.G., 1984. Shelf and shallow marine sands. In: R.G. Walker (Ed.), Facies Models, 2nd Edition. Geoscience Canada, Reprint Series 1: 141-170.
- Webber, P.J., Richardson, J.W., and Andrews, J.T., 1970. Post-glacial uplift and substrate age at Cape Henrietta-Maria, southeastern Hudson Bay, Canada. Canadian Journal of Earth Sciences, 7: 317-325.
- Weeks, W.F., Barnes, P.W., Rearic, D.M. and Reimnitz, E., 1983. Statistical aspects of ice gouging on the Alaskan Shelf of the Beaufort Sea. CRREL Report 83-21: 34p.
- Weertman, J. and Birchfield, G.E., 1982. Subglacial water flow under ice-streams and West Antarctic ice-sheet stability. Annals of Glaciology, 3: 316-320.
- Whittaker, S., Chevelier, B. and Geerlott, H. 1985. Iceberg scouring in Hudson Bay (Abstr.). In: Arctic Land-Sea Interaction, Abstracts. 14th Arctic Workshop: 91.
- Winterhalter, B. 1966. Iron-manganese concretions from the Gulf of Bothnia and the Gulf of Finland. Geoteknillsia Julkaisuja, 69: 1-77.
- _____ 1972. On the geology of the Bothnian Sea, an epeiric sea that has undergone Pleistocene glaciation. Geological Survey of Finland, Bulletin 258: 66p.
- Wyatt, P.H. 1987. The amino acid geochronology of Quaternary sediments in central Hudson Bay Lowlands, M.Sc. thesis, INSTAAR, University of Colorado, Boulder, Colorado.

Zevenhuisen, J., 1986. Data Report - Index of seismic and sample information, Hudson Bay. Geological Survey of Canada, AGC Internal Report 86-07.

APPENDICES

- A Summary of Sample Locations and Analyses
- B Core Description and Interpretation
- C Grain-size Analyses
- D Appmap Programs: Plotting Method for Grain-size Data
- E Lithological Analyses
- F Heavy Mineral Analyses
- G Geochemical Analyses
- H Mineralogy of Clay-size Fraction
- I Leco Carbonate Determinations
- J Trend Surface Analyses of Heavy Mineral Data

APPENDIX A

Summary of Surficial Sediment Sample Locations and Analyses, Hudson Bay

Sample No.: 61HU - 1961 M/V Theta (Leslie, 1964, 1965)
 65HU - 1965 CSS Hudson 65-24
 65TH - 1965 M/V Theron 65-20
 71ML - 1971 Hudson Handler (Lewis and Sanford, 1971)
 84GM/ICG - 1984 Geomarine Associates Ltd.
 86HU - 1986 CSS Hudson 86-028

Analyses: Grain - Textural
 Chem - Geochemical (<0.002mm fraction)
 Heavy - Heavy Mineral (0.063 - 0.250mm fraction)
 Gran - Lithological (2.0 - 5.6mm fraction)
 CO3 - Carbonate Determination (<0.063mm fraction)
 X-ray - X-ray (<0.002mm fraction)

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
61HU 0003	17	602116	6905275	165					
61HU 0005	17	604746	6875592	140					
61HU 0008	17	651107	6814097	58	x			x	
61HU 0009	17	614747	6810923	132	x				
61HU 0011	17	514278	6802489	109	x			x	
61HU 0012				194	x				
61HU 0013				208	x				
61HU 0015	17	388289	6875814	51	x			x	
61HU 0021	16	370814	6932190	170	x				
61HU 0022	16	344279	6907333	154	x				
61HU 0024	15	570708	6874713	101	x			x	
61HU 0026	15	557615	6874466	51	x				
61HU 0027				93	x				
61HU 0030	15	540565	6762815	119	x				
61HU 0032	16	441240	6751929	176					
61HU 0034	17	336587	6740364	188	x				
61HU 0037	17	590157	6763730	154					
61HU 0040	17	620962	6733102	56				x	
61HU 0042				150	x				
61HU 0044				161	x				
61HU 0045	17	609708	6652835	124	x				
61HU 0047				115	x				
61HU 0051	17	530032	6497312	119				x	
61HU 0055	16	567338	6523727	110	x				
61HU 0056	16	453083	6542023	201	x				
61HU 0057	15	604335	6576578	124	x				
61HU 0060	15	448291	6540191	37				x	
61HU 0063	15	519132	6539890	93	x			x	
61HU 0064	15	516361	6515714	77	x			x	
61HU 0066	15	500000	6578817	64	x			x	
61HU 0068	15	439290	6577410	71	x				
61HU 0069	15	410844	6577973	33				x	
61HU 0071	15	434907	6651778	93	x				
61HU 0073	15	513016	6645659	95				x	
61HU 0076	16	356896	6702254	137	x			x	
61HU 0079	16	554006	6646921	205	x				
61HU 0081	17	444221	6651626	137	x				
61HU 0084	17	486451	6493434	177	x				
61HU 0088	17	624137	6461959	50				x	
61HU 0089	17	644516	6466441	88	x			x	
61HU 0090				47	x				
61HU 0091	17	644468	6440362	101	x				

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
61HU 0093	18	384066	6300193	80	x				
61HU 0095	18	342955	6177200	198	x				
61HU 0097				172	x				
61HU 0100				150	x				
61HU 0102	17	564339	6069106	35	x		x		
61HU 0103	17	538604	6068813	106	x		x		
61HU 0104	17	502123	6068648	85	x				
61HU 0110	17	471131	6244028	124	x		x		
61HU 0116				144	x				
61HU 0118	16	631078	6168879	48	x		x		
61HU 0121	16	582075	6366200	93	x				
61HU 0123	16	470623	6452768	165	x		x		
61HU 0125	16	366104	6545855	124	x		x		
61HU 0148	18	347905	6985261	165			x		
61HU 0154	17	465442	6989250	230	x				
61HU 0161	16	638459	6967921	132	x		x		
61HU 0169	16	422856	7077372	58	x		x		
61HU 0194	16	404724	6399898	75			x		
61HU 0196	17	626241	6226313	64	x				
61HU 0207	17	603656	6302877	70			x		
61HU 0210	17	534537	6306185	110			x		
61HU 0216	16	596420	6307157	106			x		
61HU 0218	16	479716	6306091	58	x		x		
61HU 0223	15	584033	6460902	72			x		
61HU 0225	15	518274	6526858	82	x		x		
61HU 0226	15	504784	6526818	46			x		
65HU 0001	17	621947	6863679	101	x				
65HU 0003					x				
65HU 0004				117	x				
65HU 0006				27	x				
65HU 0007				53	x				
65HU 0009	15	495279	6578820	68	x				
65HU 0010	15	493420	6610375	68	x				
65HU 0011	15	495358	6641963	91	x				
65HU 0012	15	595199	6555505	101	x				
65HU 0013	15	593967	6574413	113	x				
65HU 0015	15	589531	6601228	121	x				
65HU 0017	15	592562	6631011	145	x				
65HU 0019	16	369022	6575510	137	x				
65HU 0020	16	375292	6592758	140	x				
65HU 0023	16	374720	6631969	152	x				
65HU 0025	16	392937	6347186	146	x				
65HU 0028	16	486928	6661622	199	x				
65HU 0029	16	458861	6673710	203	x		x		
65HU 0030	16	432855	6690804	170	x				
65HU 0031	16	405555	6702553	161	x				
65HU 0032	16	435858	6780246	181	x				
65HU 0035	16	392136	6803235	148	x				
65HU 0039	16	417600	6823900	170	x				
65HU 0042	16	456626	6929036	165	x				
65HU 0045	16	533540	6591030	199	x				
65HU 0047	16	552227	6572124	170	x				
65HU 0048	16	562662	6572839	130	x				
65HU 0052	16	530300	6582651	201	x				
65HU 0056	16	537516	6618539	196	x				
65HU 0058	16	563516	6634114	188	x				
65HU 0060	16	546101	6606941	185	x				
65HU 0064	16	495292	6603876	210	x				
65HU 0066	16	480142	6587778	201	x				
65HU 0068	16	510682	6588855	203	x				
65HU 0070	16	572321	6554261	79	x				

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
65HU 0072	16	569226	6524689	82	x				
65HU 0073	16	536077	6570637	181	x		x		
65HU 0077	16	538546	6563237	177	x				
65HU 0079	16	598954	6601464	146	x				
65HU 0081	17	331185	6611203	126	x				
65HU 0083	17	377520	6603086	192	x				
65HU 0084	17	481289	6624300	134	x		x		
65HU 0086	17	530391	6631839	155	x				
65HU 0088	17	457747	6655530	137	x				
65HU 0090	17	453514	6687697	68	x				
65HU 0092	17	463405	6711755	102	x				
65HU 0093	17	460852	6727524	112	x				
65HU 0096	16	660070	6624013	117	x				
65HU 0098	16	654410	6651649	137	x				
65HU 0100	16	656776	6683342	159	x				
65HU 0101	16	656118	6698219	170	x		x		
65HU 0102	16	582062	6597864	148	x				x
65HU 0103	16	597467	6586013	145	x				
65HU 0105	16	500949	6573250	199	x				
65HU 0107	16	475232	6556960	188	x			x	
65HU 0110	16	496571	6561187	203	x				
65HU 0112	16	513191	6546547	203	x				
65HU 0114	16	504795	6518466	192	x				
65HU 0117	16	528330	6528812	185	x				
65HU 0118	16	594496	6513157	35	x				
65HU 0122	16	565583	6483827	119	x		x		
65HU 0124	16	533513	6484312	174	x				
65HU 0126	16	502156	6484169	161	x		x		
65HU 0128	16	474759	6483693	190	x		x		
65HU 0130	16	444617	6483632	163	x				
65HU 0132	16	414790	6484168	155	x				
65HU 0134	16	385337	6484956	106	x				
65HU 0136	16	356249	6486808	90	x				
65HU 0138	16	329452	6487884	119	x				
65HU 0140	15	649611	6486099	139	x				
65HU 0142	15	619415	6487884	77	x				x
65HU 0144	15	590329	6485545	71	x				
65HU 0145	15	574782	6485625	72	x				
65HU 0146	15	560719	6485419	62	x		x		
65HU 0147	15	545636	6484435	71	x				
65HU 0149	15	573112	6470930	64	x		x		
65HU 0151	15	598395	6459006	71	x				x
65HU 0153	15	626084	6446868	81	x				x
65HU 0155	15	653525	6435129	66	x		x		
65HU 0157	16	325586	6423948	79	x				x
65HU 0159	16	351996	6411741	81	x		x		x
65HU 0161	16	379787	6396888	75	x				x
65HU 0163	16	404831	6384192	64	x		x		
65HU 0165	16	432531	6370609	60	x				x
65HU 0168	15	457865	6538181	36	x				
65HU 0170	16	564238	6749016	190	x				x
65HU 0172	16	595017	6749927	207	x				x
65HU 0174	16	621725	6750740	203	x				x
65HU 0175	16	568809	6923707	126	x				x
65HU 0177	16	592464	6908674	128	x				
65HU 0179	16	620111	6897508	119	x				
65HU 0181	16	640049	6877757	119	x				x
65HU 0183	17	357794	6878850	126	x				x
65HU 0184	17	372548	6875476	71	x				x
65HU 0186	16	569517	6973092	91	x				x
65HU 0188	16	597386	6977035	97	x				x

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
65HU 0190	16	625155	6982219	113	x			x	
65HU 0192	16	643302	7011748	99	x			x	
65HU 0194	17	364368	7034730	90	x				
65HU 0196	17	384461	7052676	88	x				
65HU 0198	17	398885	7032894	117	x			x	
65HU 0200	17	432439	7025099	123	x				
65HU 0202	17	461375	7017191	155	x				
65HU 0204	17	478147	6997497	225	x				
65HU 0206	17	500168	6985761	276	x			x	
65HU 0207	17	525225	6998487	214	x				
65HU 0208	17	544437	7007980	236	x				
65HU 0212	17	559972	6984084	285	x				
65HU 0214	17	534153	6948427	276	x				
65HU 0216	17	517192	6926012	185	x				
65HU 0217	17	465935	6872292	223	x				
65HU 0218	17	473144	6844747	196	x				
65HU 0219	17	479582	6816482	163	x				
65HU 0221	17	485680	6788231	143	x				
65HU 0223	17	492329	6758878	126	x				
65HU 0225	17	499089	6728239	106	x				
65HU 0226	17	390702	6785817	192	x				
65HU 0228	17	402512	6758909	185	x				
65HU 0230	17	415401	6731094	177	x				
65HU 0232	17	424839	6703587	163	x				
65HU 0234	17	438876	6676774	161	x				
65HU 0237	16	555666	6659050	199	x				
65HU 0238	16	565172	6646210	187	x				
65HU 0240	16	625335	6485060	101	x				
65HU 0242	16	652525	6486211	130	x				
65HU 0244	17	337723	6599020	145	x				
65HU 0246	17	367434	6597856	185	x				
65HU 0248	17	402818	6483518	177	x				
65HU 0250	17	417961	6510088	166	x				
65HU 0252	17	432411	6535797	148	x				
65HU 0254	17	447151	6561552	137	x				
65HU 0257	17	495145	6486027	152	x				
65HU 0259	17	525256	6484250	90	x				
65HU 0261	17	555369	6484560	130	x				
65HU 0263	17	585480	6485102	141	x				
65HU 0266	16	559735	6386633	104	x				
65HU 0268	16	591558	6387784	79	x				
65HU 0270	16	621209	6389491	108	x				
65HU 0272	16	653046	6390570	152	x				
65HU 0274	15	443994	6667223	104	x				
65HU 0276	15	442302	6635838	82	x				
65HU 0278	15	438827	6606043	77	x				
65HU 0280	15	435535	6577472	59	x				
65HU 0282	15	432132	6546011	42	x				
65HU 0290	17	496689	6474892	148	x				
65HU 0291	17	495093	6444089	119	x				
65HU 0292	17	495056	6414585	104	x				
65HU 0293	17	494520	6383414	104	x				
65HU 0294	17	493476	6353357	123	x				
65HU 0295	17	492418	6324045	154	x				
65HU 0297	17	510696	6291584	165	x				
65HU 0298	17	493374	6275992	154	x				
65HU 0299	17	467350	6258860	132	x				
65HU 0300	17	442223	6236864	106	x				
65HU 0301	17	418242	6225567	82	x				
65HU 0302	17	391161	6239532	81	x				
65HU 0303	17	364231	6252929	90	x				

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
65HU 0304	17	336441	6266537	126	x				
65HU 0305	16	679423	6279813	165	x				
65HU 0306	16	651371	6291337	163	x				
65HU 0307	16	622514	6301346	113	x				
65HU 0308	16	596419	6308085	102	x				
65HU 0309	16	566688	6326059	82	x				
65HU 0310	16	541305	6335970	60	x		x		
65HU 0311	16	510574	6339450	46	x		x		
65HU 0312	16	481696	6345044	45	x				
65HU 0313	16	448332	6353678	90	x		x		
65HU 0314	16	450567	6334167	77	x		x		
65HU 0315	16	477550	6322429	64	x				
65HU 0316	16	504076	6311053	75	x				
65HU 0317	16	531527	6298739	55	x		x		
65HU 0318	16	559164	6286422	66	x				
65HU 0319	16	586961	6274473	101	x				
65HU 0320	16	614420	6262137	128	x				
65HU 0321	16	641523	6250146	152	x				
65HU 0322	16	667876	6235135	137	x				
65HU 0323	17	321193	6221091	95	x				
65HU 0324	17	351950	6210265	70	x				
65HU 0325	17	377010	6196484	59	x				
65HU 0326	17	402728	6180056	42	x		x		
65HU 0327	17	426081	6169021	71	x				
65HU 0328	17	448398	6149594	66	x				
65HU 0329	17	469331	6130849	70	x				
65HU 0330	17	491507	6114058	82	x				
65HU 0508									
65TH 0028	17	531462	6916832	176	x		x		
65TH 0030	17	506045	6910190	199	x				
65TH 0031	17	494813	6907404	214	x				
65TH 0033	17	466205	6899214	219	x				
65TH 0036	17	428694	6888655	110	x		x		
65TH 0038	17	404192	6882239	70	x		x		
65TH 0041	17	368042	6872861	140	x				
65TH 0042	17	354846	6871168				x		
65TH 0044	16	646374	6862297	165	x		x		
65TH 0046	16	623014	6853014	179	x				
65TH 0051	16	562757	6831845	384	x		x		x
65TH 0053	16	538997	6822211	230	x				
65TH 0055	16	515089	6812741	225	x		x		x
65TH 0057	16	491094	6805294	230	x				
65TH 0059	16	466514	6796160	180	x				
65TH 0061	16	443597	6787207	195	x				
65TH 0064	16	407439	6775270	195	x		x		x
65TH 0065	16	395002	6770640	205	x				
65TH 0066	16	383366	6766732	157	x		x		x
65TH 0067	16	371059	6763034	161	x				
65TH 0071	15	649566	6745334	135	x				
65TH 0073	15	626790	6735087	132	x				
65TH 0075	15	602519	6725061	128	x				
65TH 0077	15	577193	6715700	126	x				
65TH 0078	15	583627	6732928	138	x				
65TH 0080	15	586237	6758061	108	x		x		x
65TH 0082	15	588733	6783752	115	x		x		x
65TH 0084	15	590760	6809212	130	x		x		x
65TH 0086	15	593460	6833802	143	x				x
65TH 0088	15	594291	6859459	130	x				x
65TH 0090	15	596616	6885049	113	x				x
65TH 0092	15	598076	6910171	95	x		x		x
65TH 0094	15	588598	6925288	87	x		x		

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
65TH 0095	15	596246	6937539	50	x				
65TH 0099	15	572966	6891477	76	x				
65TH 0101	15	559703	6868931	84	x				
65TH 0103	15	543995	6845852	95	x				
65TH 0105	15	530135	6823979	98	x				
65TH 0107	15	515134	6802493	92	x				
65TH 0109	15	498224	6782076	102	x				
65TH 0111	15	482849	6761733	88	x				
65TH 0113	15	504776	6749999	106	x				
65TH 0117	15	548977	6721147	117	x				
65TH 0119	15	571340	6711309	128	x				
65TH 0120	15	557666	6708242	122	x	x	x	x	
65TH 0123	15	520228	6694919	101	x				
65TH 0125	15	495416	6688294	104	x				
65TH 0130	15	483039	6601128	62	x	x	x	x	
65TH 0132	15	515299	6550118	77	x	x	x	x	
65TH 0133	15	516784	6537986	77	x				
65TH 0134	15	519730	6524081	75	x	x			
65TH 0136	15	522529	6499043	62	x				
65TH 0137	15	543516	6502005	70	x	x	x	x	
65TH 0138	15	541931	6514459	132	x	x	x	x	
65TH 0139	15	540347	6527620	81	x				
65TH 0140	15	558661	6555140	88	x				
65TH 0145	15	589547	6561272	102	x				
65TH 0146	15	603011	6556042	102	x	x			x
65TH 0148	15	632098	6543007	110	x	x			
65TH 0149	15	655932	6534278	188	x				
65TH 0150	15	651566	6559556	137	x	x			x
65TH 0151	15	649168	6572504	130	x				
65TH 0152	16	363397	6577603	128	x	x			x
65TH 0154	16	404302	6580361	164	x		x		
65TH 0156	16	406503	6554906	174	x				
65TH 0157	16	435901	6555191	195	x				
65TH 0159	16	431982	6591903	198	x				
65TH 0161	16	492071	6647537	200	x				
65TH 0163	16	493534	6685513	209	x				
65TH 0164	16	496304	6692080	200	x				
65TH 0165	16	494492	6697614	195	x				
65TH 0166	16	496320	6707784	197	x	x			x
65TH 0170	16	424709	6804238	175	x				
65TH 0171	16	434188	6809654	197	x		x		
65TH 0174	16	470807	6828650	164	x	x	x	x	x
65TH 0178	16	375341	6904140	170	x	x			x
65TH 0180	16	375158	6933920	170	x	x	x	x	
65TH 0185	16	348849	6987002	132	x				
65TH 0186	15	639268	6988368	102	x	x	x	x	
65TH 0187	16	355286	6941196	155	x				
65TH 0189	15	641764	6929914	126	x				
65TH 0191	15	625252	6933936	106	x	x	x	x	
65TH 0192	15	629288	6941450	70	x				x
65TH 0193	15	632231	6952719	113	x				
65TH 0200	15	625417	7008214				x		
65TH 0201	15	625658	7012350	44	x				
65TH 0204									
65TH 0205	15	621885	7025589	81	x				
65TH 0206	15	619529	7028288	86	x				
65TH 0207	15	618421	7027132	98	x				
65TH 0209	15	629449	7022353	89	x				
65TH 0210	15	625768	7022392	89	x				
65TH 0211	15	622405	7021147	66	x				
65TH 0212	15	618606	7022120	50	x				x

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
65TH 0213	15	621954	7021130	55	x				
65TH 0214	15	626987	7020767	65	x				
65TH 0215	15	629114	7020294	54	x		x	x	
65TH 0216	15	633069	7019340	51	x				
65TH 0217	15	636559	7018371	50	x		x	x	
65TH 0218	15	640982	7021016	55	x				
65TH 0220	15	643094	7016424	66	x	x	x	x	
65TH 0222	15	643589	7005290	128	x				x
65TH 0223	16	348083	6896003	166	x		x		
65TH 0224	16	364391	6846910	164	x	x	x	x	
65TH 0226	16	411157	6882607	154	x	x	x	x	
65TH 0228	16	420023	6813628	163	x	x	x	x	
65TH 0229	16	489273	6792303	178	x				
65TH 0230	16	451527	6746204	200	x	x			x
65TH 0231	16	459116	6734970	163	x				
65TH 0232	16	467122	6716286	201	x	x	x	x	
65TH 0234	16	487039	6661473	210	x	x	x	x	
65TH 0235A	16	490248	6654892	215	x				
65TH 0235B	16	490248	6654892	215	x				
65TH 0236	16	509854	6615914	216	x	x	x	x	
65TH 0237	16	510854	6601105	212	x				
65TH 0238	16	508053	6589071	210	x	x			x
65TH 0244	16	596055	6604211	180	x	x	x	x	
65TH 0245	16	617239	6604813	144	x				
65TH 0246	16	635236	6588700	130	x				
65TH 0247	16	634922	6571971	130	x		x		
65TH 0250	16	638286	6609208	154	x		x	x	
65TH 0252	17	355327	6615023	135	x	x	x	x	
65TH 0254	17	418290	6614009	190	x	x	x	x	
65TH 0257	17	426125	6582322	165	x				
65TH 0258	17	434360	6565464	140	x	x	x	x	
65TH 0259	17	434372	6592418	165	x		x	x	
65TH 0260	17	434630	6607227	152	x	x	x	x	
65TH 0261	17	434367	6621155	154	x				
65TH 0263	17	464831	6618888	118	x				
65TH 0264	17	482188	6624296	122	x				
65TH 0265	17	469937	6612346	123	x		x	x	
65TH 0266	17	488743	6617811	144	x				
65TH 0267	17	510276	6626161	162	x				
65TH 0268	17	534756	6662506	155	x				
65TH 0269	17	553770	6661806	150	x			x	x
65TH 0271	17	591354	6661583	155	x				
65TH 0272A	17	600343	6661583	143	x	x	x	x	
65TH 0272B	17	600343	6654463	143	x	x		x	
65TH 0273	17	629875	6634876	130	x				
65TH 0274	17	620951	6650401	128	x	x			
65TH 0275	17	609542	6658402	141	x			x	x
65TH 0277	17	582906	6685559	160	x				
65TH 0279	17	551241	6708145	170	x				
65TH 0280	17	535589	6719096	140	x				
65TH 0281	17	522754	6731133	112	x	x		x	
65TH 0282	17	504655	6630827	159	x	x			
65TH 0284	17	467284	6629074	143	x	x	x	x	x
65TH 0285	17	452031	6608078	135	x		x	x	
65TH 0286	17	439499	6590438	130	x				
65TH 0287	17	423153	6575921	165	x			x	
65TH 0288	17	421919	6562914	148	x		x	x	
65TH 0289	17	403923	6566110	176	x	x	x	x	
65TH 0290	17	387817	6569337	200	x	x			
65TH 0291	17	394978	6586736	180	x		x	x	
65TH 0292	17	402031	6602367	255	x	x			

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
65TH 0293	17	409972	6619770	155	x				
65TH 0295	17	335594	6593538	113	x				
65TH 0296	17	334784	6574952	137	x	x	x	x	
65TH 0297	17	333981	6556478	150	x				
65TH 0299	16	643656	6553677	150	x				
65TH 0300	16	638955	6564648	121	x	x	x	x	
65TH 0301	16	611715	6585145	139	x				
65TH 0302	16	597968	6602367	155	x	x		x	
65TH 0303	16	574273	6585115	126	x				
65TH 0304	16	536327	6597924	199	x	x		x	
65TH 0317	15	616231	6582458	118	x				
65TH 0320	15	570495	6559090	106	x	x	x	x	
65TH 0321	15	544354	6554910	106	x				
65TH 0323	15	494552	6547641	46	x				
65TH 0324	15	569677	6578679	113	x	x		x	
65TH 0325	15	569321	6598016	124	x				
65TH 0326	15	569430	6616546	140	x	x		x	
65TH 0327	15	569103	6635142	123	x				
65TH 0328	15	568748	6653181	132	x	x	x	x	x
65TH 0330	15	531626	6651340	101	x	x	x	x	
65TH 0332	15	550367	6671931	123	x	x	x	x	
65TH 0333	15	586322	6657784	135	x				
65TH 0335	15	623863	6660156	155	x				
65TH 0336	15	642372	6661421	157	x	x		x	
65TH 0337	15	661399	6662207	166	x				
65TH 0338	16	346787	6658066	134	x	x	x	x	x
65TH 0339	16	362669	6660672	137	x				
65TH 0340	16	382148	6659996	150	x	x	x	x	
65TH 0341	16	400084	6659985	157	x				
65TH 0342	16	401680	6677919	146	x	x	x	x	
65TH 0343	16	402221	6697999	163	x				
65TH 0344	16	402307	6717460	161	x	x	x	x	x
65TH 0345	16	402812	6736056	172	x				
65TH 0346	16	386820	6725381	149	x		x	x	
65TH 0347	16	371926	6737363	161	x				
65TH 0348	16	387495	6746759	155	x	x	x	x	
65TH 0349	16	421333	6731887	176	x				
65TH 0350	16	441678	6735546	192	x			x	
65TH 0351	16	460915	6734950	194	x				
65TH 0352	16	480920	6734787	201	x	x	x	x	x
65TH 0353	16	500000	6734736	205	x				
65TH 0354	16	519510	6735681	212	x	x	x	x	
65TH 0355	16	519181	6715667	207	x				
65TH 0356	16	519276	6697661	220	x				
65TH 0357	16	536472	6674551	190	x				
65TH 0358	16	551836	6600519	201	x				
65TH 0359	16	561326	6612728	180	x				
65TH 0360	16	573725	6627210	180	x	x		x	
65TH 0361	16	582955	6642296	180	x				
65TH 0362	16	581118	6661343	183	x	x		x	
65TH 0363	16	582081	6681269	184	x				
65TH 0365	16	546238	6742461	180	x				
65TH 0366	16	550259	6777199	249	x	x		x	
65TH 0367	16	545484	6800566	220	x				
65TH 0368	16	526328	6800220	223	x		x	x	
65TH 0369	16	508722	6800132	221	x			x	
65TH 0370	16	521553	6776015	220	x	x		x	
65TH 0371	16	535697	6799858	220	x	x	x	x	x
65TH 0375	16	567621	6940584	124	x				
65TH 0377	16	541819	6951338	123	x	x			
65TH 0378	16	531055	6958239	113	x	x	x	x	

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
65TH 0379	16	511070	6962233	113	x				
65TH 0380	16	476081	6949266	100	x				
65TH 0381	16	458173	6949444	110	x		x		
65TH 0382	16	458767	6928489	118	x				
65TH 0383	16	475944	6927912	126	x	x	x	x	
65TH 0385	16	517171	6930097	128	x				
65TH 0386	16	535196	6928977	124	x				
65TH 0389	16	605987	6946644	124	x		x		
65TH 0391	16	626632	6954395	128	x				
65TH 0395	17	397107	7003739	146	x				
65TH 0396	17	415977	7001708	160	x				
65TH 0398	17	450837	7000582	223	x				
65TH 0400	17	484403	6990070	263	x	x	x	x	
65TH 0402	17	459075	6953333	205	x	x			x
65TH 0403	17	505137	6938933	225	x				
65TH 0405	17	519060	6902775	167	x		x		
65TH 0406	17	524380	6885206	137	x	x	x		
65TH 0407	17	515735	6869335	143	x		x	x	
65TH 0408	17	505275	6849808	148	x	x	x		
65TH 0409	17	531684	6846274	161	x		x		
65TH 0410	17	490149	6854831	181	x	x			
65TH 0411	17	494756	6870306	183	x				x
65TH 0412	17	501721	6887013	185	x	x	x		
65TH 0418	17	452581	6854254	229	x	x			x
65TH 0419	17	438176	6834613	219	x				x
65TH 0420	17	423855	6846972	227	x	x			
65TH 0421	17	410811	6859322	209	x				x
65TH 0422	17	396433	6871320	135	x				
65TH 0424	17	370149	6870326	139	x		x		
65TH 0426	17	398312	6846184	229	x	x	x	x	
65TH 0427	17	412542	6834202	229	x				x
65TH 0429	17	422406	6820037	216	x				
65TH 0433	17	358144	6757061	110	x				
65TH 0434	17	340290	6741424	190	x				
65TH 0436	16	636819	6765225	215	x	x	x	x	
65TH 0437	16	623895	6778684	205	x				x
65TH 0438	16	634864	6792132	210	x	x			
65TH 0439	16	651734	6779773	219	x				x
65TH 0440	17	340563	6768068		x				
65TH 0443	16	653139	6725412	183	x		x	x	
65TH 0444	16	637351	6708609		x				
65TH 0447	16	550514	6628494				x	x	
65TH 0448	16	548428	6646287						
65TH 0449	16	530699	6628500		x				x
65TH 0452	16	642856	6511628		x		x		
65TH 0453	16	636093	6527544		x		x	x	
65TH 0454	16	647493	6546355		x		x		
65TH 0455	16	662002	6540251				x	x	
65TH 0456	16	655370	6526266		x		x	x	
65TH 0458	17	346943	6496969		x				x
65TH 0459	17	369554	6485785						x
65TH 0461	17	415907	6458118			x			
65TH 0462	17	442533	6440382	150	x		x		
65TH 0463	17	433423	6424377				x	x	
65TH 0464	17	442978	6401069				x		
65TH 0465	17	420319	6384192	132	x		x	x	
65TH 0466	17	376478	6386182		x				
65TH 0468	17	384949	6420911		x	x	x	x	
65TH 0470	17	388857	6346506	165	x	x	x	x	
65TH 0474	17	382780	6291319		x				x
65TH 0475	17	372578	6273684						x

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CNEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
65TH 0476	16	520266	6309764	x			x	x	
65TH 0477	16	529518	6335090				x	x	
65TH 0479	16	528189	6387182	128	x				
65TH 0480	16	528576	6424927		x	x			x
65TH 0481	16	510348	6427065		x		x	x	
65TH 0482	16	492138	6428841	159	x	x	x	x	
65TH 0483	16	473726	6433262	135	x				
65TH 0484	16	456526	6437086		x	x			x
65TH 0486	16	474038	6453858	167	x	x	x	x	x
65TH 0488	16	510731	6460022		x	x			x
65TH 0490	16	440889	6428936		x	x		x	
65TH 0491	16	421187	6429277	157	x				
65TH 0492	16	404422	6429643				x		
65TH 0493	16	386692	6430107	81	x				
65TH 0494	16	368964	6430649	83	x		x		
65TH 0496	16	330381	6432103		x		x	x	
65TH 0497	15	666487	6431971	73	x				
65TH 0498	15	648053	6431244			x		x	
65TH 0499	15	631035	6430649	64	x			x	
65TH 0500	15	613307	6430107			x		x	x
65TH 0501	15	594572	6429619	73	x		x		
65TH 0502	15	575873	6427327	55	x	x	x	x	
65TH 0503	15	559110	6428936	48	x		x		
65TH 0504	15	558821	6448419				x	x	
65TH 0505	15	558553	6466455	70	x		x	x	x
65TH 0506	15	557273	6485924	73	x		x		
65TH 0507	15	557973	6505423	77	x				
65TH 0508	15	556708	6524447	84	x	x		x	
65TH 0509	15	557411	6543056	93	x				
65TH 0510	15	557044	6567553	117	x		x	x	
65TH 0511	15	538956	6567881				x		
65TH 0512	15	520419	6567736		x		x	x	
65TH 0513	15	501882	6567682	62	x		x		
65TH 0514	15	482888	6567720	51	x	x	x	x	
65TH 0515	15	463895	6567853				x		
65TH 0516	15	445326	6567146	73	x				
65TH 0517	15	442705	6550850				x		
65TH 0520	16	374831	7024934	128	x	x	x	x	
65TH 0523	16	429045	7023278	177	x	x	x	x	
65TH 0529	16	486344	6953887	109	x				
65TH 0532	16	487037	6908316	141	x		x		
65TH 0538	16	585388	6880623	165	x	x			x
65TH 0544	17	382031	6846259	185	x		x		
65TH 0547	17	393028	6803208	205	x				
65TH 0548	17	410835	6802707	212	x	x			x
65TH 0550	17	449184	6801939	194	x	x			x
65TH 0553	17	538811	6837100	135	x				
65TH 0555	17	517916	6781230	99	x		x		
65TH 0560	17	603676	6764100	137	x	x			x
65TH 0563	17	627301	6784380	113	x				
65TH 0566	17	635458	6850695	104	x	x		x	
65TH 0575	17	629141	6945236	502	x				
65TH 0577	17	627169	6963003	388	x				
65TH 0579	18	358929	6966136	438	x				
65TH 0582	18	417555	6964141	378	x				
71MLA0001	17	386413	7091415	60	x		x		
71MLA0002	17	373915	7043596	82	x		x		
71MLA0003	16	642413	7003341	104	x		x	x	
71MLA0004	16	606339	6961148	117	x		x		
71MLB0001	16	551517	6930081	119	x		x		
71MLB0002	16	495737	6939934	124	x		x		

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
71MLB0003	16	432682	6956329	104	x		x		
71MLC0001	15	584031	6934421	51	x		x		
71MLC0002	15	621224	6898440	110	x				x
71MLC0004	16	352831	6874377	130	x		x		x
71MLC0006	16	370916	6829971	167	x				
71MLD0002	16	396831	6810561	140	x		x		
71MLD0003	16	344334	6812513	124	x		x		
71MLD0004	15	611932	6815402	115	x		x		x
71MLD0005	15	554594	6816814	126	x				
71MLD0006	15	495571	6810818	62	x		x		
71MLE0001	15	472957	6762872	82	x				
71MLE0002	15	512713	6736615	120	x				
71MLF0002	15	561419	6729693	115	x				
71MLF0004	15	624384	6725751	133	x				
71MLF0006	16	340528	6727138	130	x				
71MLF0007	16	382885	6725507	130	x				
71MLF0009	16	378289	6736806	120	x		x		x
71MLG0001	16	408010	6745167	146	x		x		x
71MLG0002	16	433537	6701932	175	x				x
71MLG0003	16	462349	6651396		x				
71MLG0004	16	481173	6601137	150	x				
71MLG0005	16	503810	6578819	150	x				
71MLG0006	16	500000	6521247	150	x				
71MLH0001	16	470781	6474034	177	x				
71MLH0002	16	479552	6474980	177	x		x		
71MLH0003	16	423295	6487704	125	x				
71MLH0004	16	364393	6496769		x				
71MLH0005	15	648496	6515741	135	x		x		
71MLH0006	15	595159	6526206	95	x		x		
71MLH0008	15	538809	6537255	87	x		x		
71MLH0009	15	480895	6545458	44	x		x		
71MLH0010	15	422721	6554543	32	x				x
71MLI0002	15	530169	6479608	65	x		x		
71MLI0003	15	563613	6454061	65	x		x		
71MLI0004	16	351493	6450764	80	x		x		
71MLI0006	16	411193	6423027	78	x		x		
71MLI0007	16	509963	6391438	130	x				
71MLI0008	16	500992	6400666	140	x				
71MLJ0001	16	479928	6349727	53	x		x		
71MLJ0002	16	510145	6317185	50	x				x
71MLJ0004	16	543927	6282116	57	x				
71MLJ0006	16	618394	6249253	120	x				
71MLJ0007	16	659413	6253380	160	x				
71MLK0002	17	403452	6258944	105	x				
71MLK0003	17	505109	6261520		x				
71MLK0004	17	466125	6259760	118	x	x			
71MLK0005	17	520495	6262457	85	x		x		
71MLL0001	17	600080	6304460	85	x		x		
71MLL0002	17	537432	6322908	78	x				
71MLL0004	17	476837	6335828	126	x				
71MLL0005	17	432599	6345555	105	x		x		
71MLL0006	17	366536	6356417	165	x		x		
71MLL0008	17	319817	6356423	177	x				
71MLL0009	16	638519	6354802	135	x		x		
71MLM0001	16	603621	6383397	85	x		x		
71MLM0003	16	608177	6472629	98	x				
71MLM0004	16	619891	6504611	95	x		x		
71MLN0001	17	346017	6523423	155	x				
71MLN0002	17	408791	6529787	200	x		x		
71MLN0003	17	494200	6503658	180	x				
71MLN0004	17	558118	6495736	118	x		x		

SAMPLE NO.	LOCATION (UTM)		DEPTH (m)	GRAIN	CHEM	HEAVY	GRAN	CO3	X-RAY
	zone	easting							
71MLN0005	17	583480	6553783	100	x		x		
71MLN0006	19	438204	6597922	110	x				
71MLN0007	17	637587	6653770	105	x				
84GM80001	16	410634	6485188	178	x				
84GM80002	16	412675	6574254	170	x				
84GMC0001	16	437830	6484662	165	x				
84ICG0001	16	470131	6636475	198	x				
84ICG0002	16	429206	6644457	176	x				
84ICG0003	16	446189	6659022	188	x				
86HU 0002	16	507808	6677775	201	x			x	
86HU 0004	16	411148	6564877	179	x				x

APPENDIX B

Core Description and Interpretation

Cores collected during geological and geophysical surveys in Hudson Bay (Fig. B.1) are listed in Table 6.

Leslie (1965) examined the texture and faunal assemblage of six cores and related the depositional environments to deglaciation of Hudson Bay based on those criteria. Core summaries of this data are shown in Figure B.2.

The remainder of the cores were collected on Hudson cruise 87-028 using a 10cm diameter piston corer. For the most part, sediment was recovered in two sections: the trigger weight (TWC), which essentially serves as the trigger for initiating free fall of the piston corer (PC), and the piston core itself. Ideally, the recovered upper portion of the piston core overlaps with the trigger weight core. In practice, this rarely occurs due to the soupy nature of the surficial unit and the force at which the piston corer contacts the seafloor.

All cores were split and examined onboard ship. Based on these descriptions, sedimentary facies have been characterized using the lithofacies code of Eyles et al (1983) with some modification (Table 7). These facies are interpreted as representative of four main depositional environments as outlined in the text: (1) post-glacial open marine, (2) glaciomarine/glaciolacustrine, (3) glacial, and (4) fluvial/glaciofluvial. A summary of the sedimentology and interpretations of nine cores collected on Hudson cruise 87-028 are presented in Figure B.3. Complete descriptions and analyses of 1987 cores have been summarized in a data report prepared by the author (Henderson, in press).

Table 6

Hudson Bay Core Data

Core Number	Location *		Core Length (cm)	Depth (m)	Reference
	Latitude	Longitude			
61HB-147	62°46'N	76°00'W	210	466	Leslie,
61HB-158	61°48'	81°58'	202	225	(1965)
61HB-177	61°44'	87°58'	107	201	"
61HB-231	59°03'	94°01'	138	51	"
61HB-084	58°35'	81°14'	102	177	"
61HB-104	54°46'	81°58'	145	85	"
<u>HU-87-028**</u>					
001 (TWC)	63°02'	81°05'	122	273	AGC,
(PC)			723		(1987)
004 (TWC)	63°01'	81°05'	112	271	"
(PC)			518		
015 (TWC)	61°35'	86°19'	136	214	"
(PC)			188		
029 (GC)	60°36'	88°11'	103	180	"
035 (GC)	60°21'	86°02'	200	183	"
041 (TWC)	57°54'	88°20'	80	182	"
(PC)			295		
043 (TWC)	55°21'	78°14'	140	118	"
(PC)			490		
074 (TWC)	55°06'	80°30'	66	95	"
(PC)			150		
090 (TWC)	58°39'	90°07'	130	155	"
(PC)			682		
(TWC)	Trigger weight core		* All locations to the		
(PC)	Piston core		nearest degree		
(GC)	Gravity core		** Cruise number		

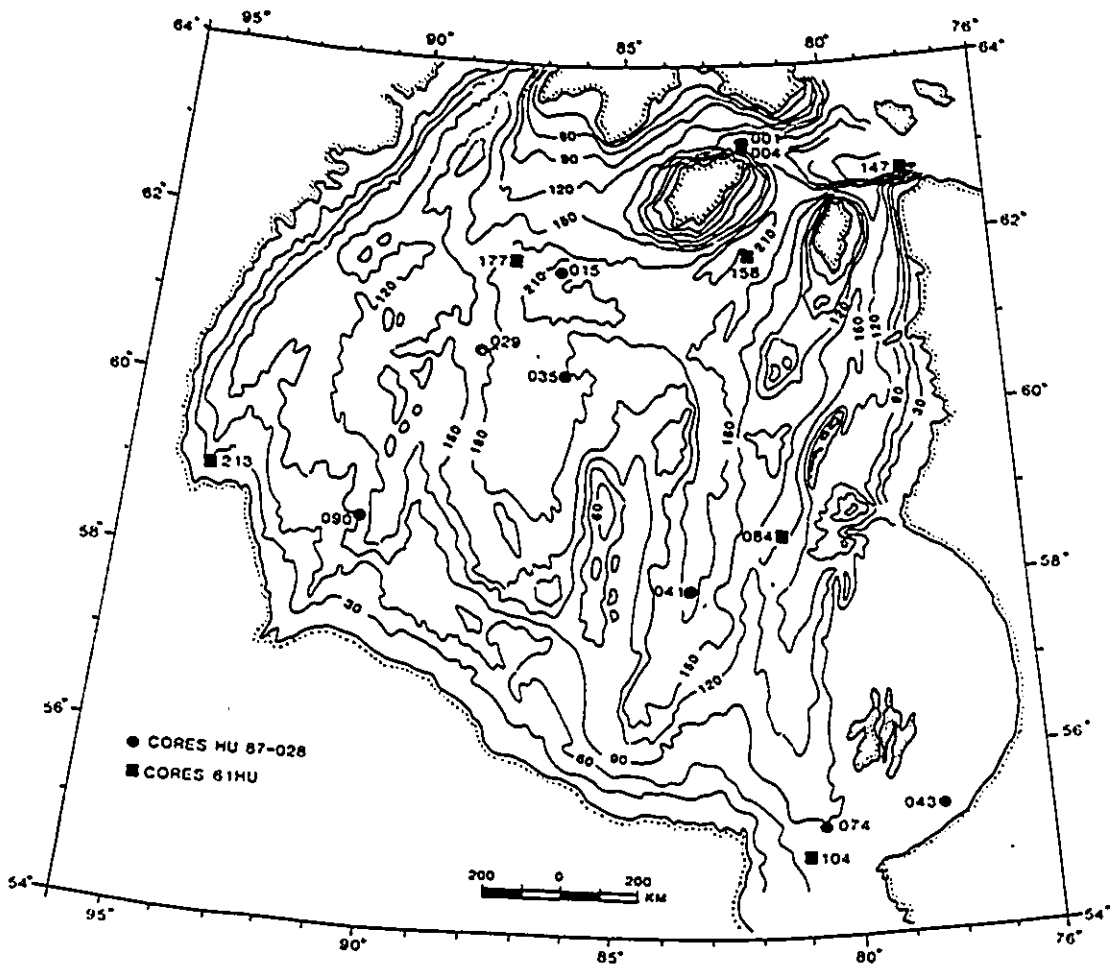


Figure B.1: Core locations, Hudson Bay.

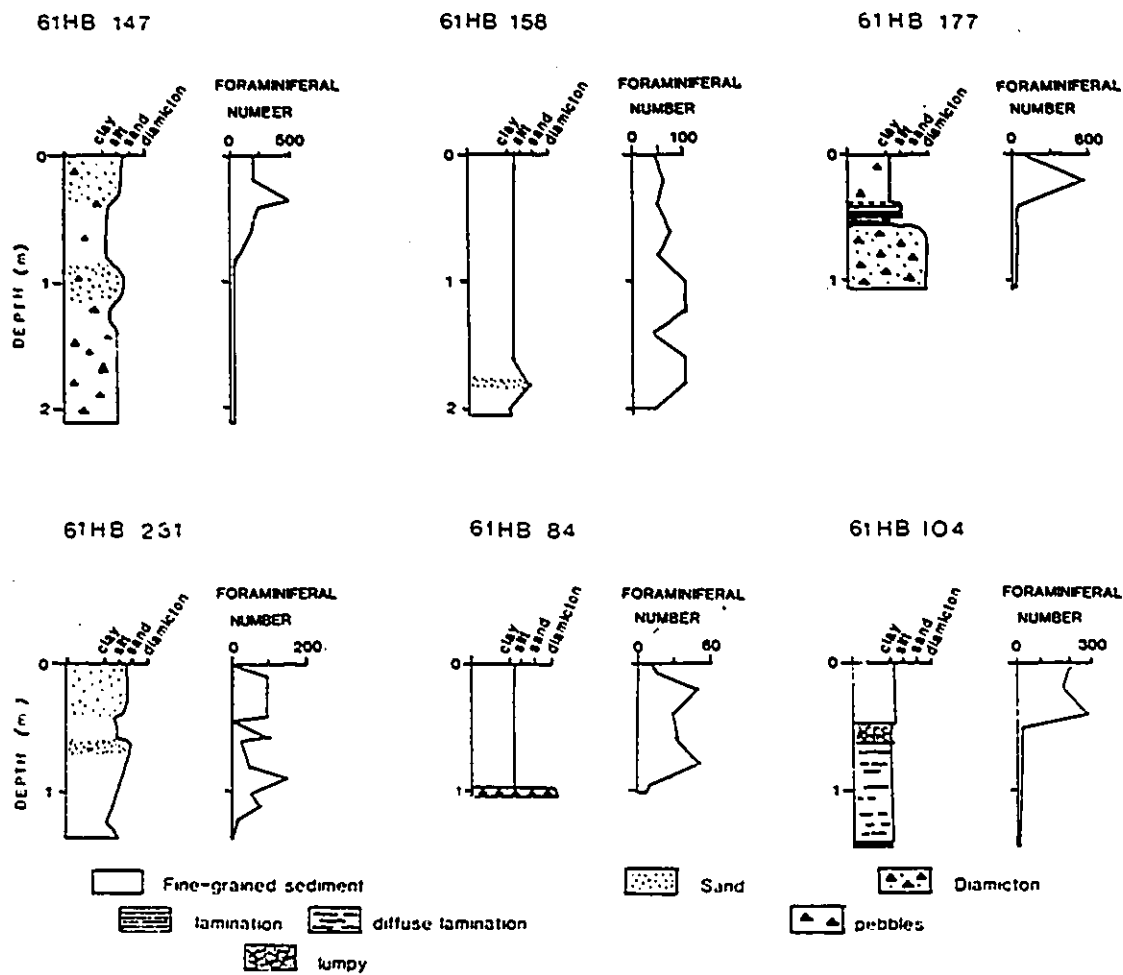


Figure B.2 Core summaries, 61HB.

TABLE 7

Diamict Lithofacies Code and Symbols
(modified from Eyles et al, 1983)

Hyphens show possible combinations: second letter (m and c) indicates matrix or clast support (degree undefined). Third letter gives internal structure. Fourth letter (in parenthesis) suggests possible useful environmental characteristics.

FACIES CODE

Diamict, D:



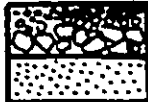






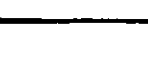

Dm : matrix supported
Dc : clast supported
D- m : massive
D- s : stratified
D- g : graded
Genetic interpretation, ()
D- -(r) : resedimented
D- -(c) : current reworked
D- -(s) : sheared

Sands, S:

Sr : rippled
St : trough cross-bedded
Sh : horizontal
lamination
Sm : massive
Sg : graded
Sd : soft sediment
deformation

Fine grained (mud), F:

F1 : laminated
Fm : massive
F-d : dropstones
Genetic Interpretation, ()
F- -(d) : deformed, dewatering
F- -(b) : biogenic reworking

SYMBOLS	
DIAMICT	
	size of symbol proportional to clast size
	stratified
	Gravel
	Sand
	Lamination (spacing prop. to thickness)
	-with silt and clay clasts
	-with dropstones
	-with loading structures
Contacts:	
	Erosional
	Conformable
	Gradational

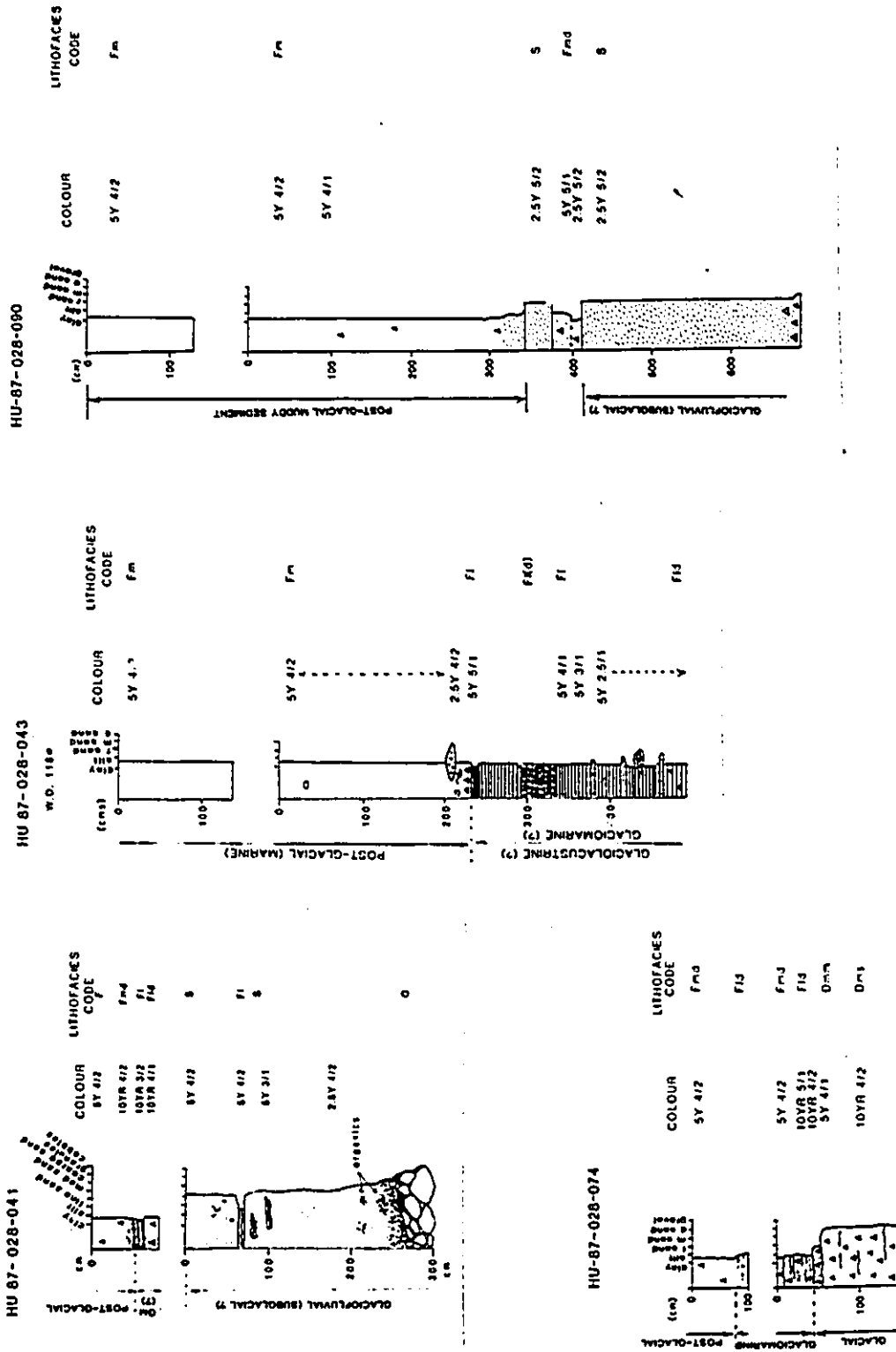


Figure B.3 (cont'd): Core summaries, HU-87-028

APPENDIX C

Textural Analyses, Hudson Bay

All samples:

- >2mm - weight percent of total sample >2mm
 % sand - weight percent sand (0.063-2mm) of matrix fraction (<2mm)
 % silt - weight percent silt (0.004-0.063mm) of matrix fraction (<2mm)
 % clay - weight percent clay (<0.004mm) of matrix fraction (<2mm)

1971 samples:

$$\text{Mean } (\phi) = M_{\phi} = \frac{\phi_{16} + \phi_{84}}{2} \quad (\text{Inman, 1952})$$

$$\text{Sorting} = \sigma_{\phi} = \frac{\phi_{84} - \phi_{16}}{2} \quad (\text{Inman, 1952})$$

where ϕ indicates a ϕ percentile

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
61HU 0008	58		61.20	24.00	14.80		
61HU 0009	132		5.50	47.1	47.4		
61HU 0011	109		21.1	35.6	43.3		
61HU 0012	194		0.3	39.5	60.2		
61HU 0013	208		2.1	54.6	43.3		
61HU 0015	51		16.0	46.9	37.1		
61HU 0021	170		0.4	70.4	29.2		
61HU 0022	154		4.1	62.6	33.3		
61HU 0024	101		41.4	36.4	22.2		
61HU 0026	51		25.8	45.8	28.4		
61HU 0027	93		56.4	29.7	13.9		
61HU 0030	119		9.9	65.8	24.3		
61HU 0034	188		7.5	42.7	49.8		
61HU 0042	150		0.3	29.8	69.9		
61HU 0044	161		0.2	23.8	76.0		
61HU 0045	124		3.8	33.0	63.2		
61HU 0047	115		11.9	34.4	53.7		
61HU 0055	110		2.8	49.1	48.1		
61HU 0056	201		2.3	30.9	66.8		
61HU 0057	124		4.2	52.3	43.5		
61HU 0063	93		55.5	27.6	16.9		
61HU 0064	77		50.4	31.4	18.2		
61HU 0066	64		38.3	34.4	27.3		
61HU 0068	71		22.5	59.7	17.8		
61HU 0071	93		50.6	40.4	9.0		
61HU 0076	137		28.3	43.4	28.3		
61HU 0079	205		2.6	30.8	66.6		
61HU 0081	137		19.3	27.3	53.4		
61HU 0084	177		0.2	22.9	76.9		
61HU 0089	88		58.3	19.0	22.7		
61HU 0090	47		78.3	11.5	10.2		
61HU 0091	106		8.0	40.4	51.6		
61HU 0093	80		7.1	34.9	58.0		
61HU 0095	198		0.7	31.0	68.3		
61HU 0097	172		1.0	32.5	66.5		
61HU 0100	150		1.2	33.0	65.8		
61HU 0102	35		50.2	22.0	27.8		
61HU 0103	106		8.1	49.8	42.1		
61HU 0104	85		2.3	48.1	49.6		
61HU 0110	124		13.5	32.9	53.6		
61HU 0116	144		5.1	64.1	30.8		
61HU 0118	48		15.5	50.7	33.8		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
61HU 0121	93		47.4	34.9	17.7		
61HU 0123	165		23.9	35.2	40.9		
61HU 0125	124		37.7	28.1	34.2		
61HU 0154	230		4.4	56.6	39.0		
61HU 0161	132		36.0	40.0	24.0		
61HU 0169	58		50.0	32.0	18.0		
61HU 0196	64		4.5	55.2	40.3		
61HU 0218	58		60.2	23.2	16.6		
61HU 0225	82		41.0	34.6	24.4		
65HU 0001	141	89.94	35.19	41.75	23.06		
65HU 0003	33	0.00	10.74	55.91	33.35		
65HU 0004	117	16.43	23.47	22.74	53.79		
65HU 0006	27	96.48	70.07	18.26	8.28		
65HU 0007	53	60.73	49.15	40.44	10.41		
65HU 0009	68	39.57	71.64	13.68	14.68		
65HU 0010	68	59.04	66.74	16.16	17.10		
65HU 0011	91	44.50	55.29	22.64	22.07		
65HU 0012	101	8.63	16.82	40.30	42.88		
65HU 0013	113	1.14	8.68	58.86	32.46		
65HU 0015	121	1.73	5.79	35.71	58.50		
65HU 0017	145	49.92	11.62	33.90	54.48		
65HU 0019	137	53.41	27.44	24.66	47.90		
65HU 0020	140	0.00	8.26	23.82	67.91		
65HU 0023	152	0.25	5.34	25.84	68.82		
65HU 0025	146	0.99	8.64	29.92	61.44		
65HU 0028	199	2.30	13.58	27.54	58.88		
65HU 0029	203	0.39	6.30	18.00	75.70		
65HU 0030	170	16.33	3.05	18.60	78.35		
65HU 0031	161	0.23	0.62	25.81	73.57		
65HU 0032	181	0.16	0.58	33.52	65.90		
65HU 0035	148	46.22	31.37	35.65	32.98		
65HU 0039	170	43.37	36.48	43.10	20.42		
65HU 0042	165	0.17	2.91	57.88	39.21		
65HU 0045	199	0.04	1.01	10.45	88.54		
65HU 0047	170	22.71	1.66	15.71	82.63		
65HU 0048	130	44.76	4.38	18.92	76.70		
65HU 0052	201	2.41	3.67	24.33	72.00		
65HU 0056	196	1.46	2.23	12.70	85.07		
65HU 0058	188	0.01	0.90	12.42	87.58		
65HU 0060	185	0.05	0.98	14.71	84.31		
65HU 0064	210	3.02	4.15	26.28	69.57		
65HU 0066	201	4.83	2.27	19.31	78.42		
65HU 0068	203	1.47	3.70	57.96	38.34		
65HU 0068	203	0.14	1.67	29.36	68.97		
65HU 0070	79	98.02	17.71	33.34	48.44		
65HU 0072	82	13.94	16.51	42.76	40.73		
65HU 0073	181	2.22	4.85	17.60	77.55		
65HU 0073	181	0.76	1.90	26.50	71.59		
65HU 0077	177	1.65	2.15	13.03	84.82		
65HU 0079	146	3.86	0.84	11.45	87.71		
65HU 0081	126	58.47	7.97	40.65	51.38		
65HU 0083	192	7.60	8.80	24.44	66.76		
65HU 0084	134	0.43	3.50	20.82	75.68		
65HU 0086	155	2.17	1.45	11.87	86.68		
65HU 0088	137	27.15	8.32	17.05	74.63		
65HU 0090	68	87.60	85.40	4.20	10.40		
65HU 0092	102	70.16	75.67	9.99	14.34		
65HU 0093	112	0.18	0.18	14.16	85.66		
65HU 0093	112	52.40	43.11	18.82	38.07		
65HU 0096	117	21.51	22.24	33.17	44.59		
65HU 0098	137	24.93	10.64	30.04	59.32		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
65HU 0100	159	6.85	12.49	30.49	57.02		
65HU 0101	170	18.95	8.97	28.20	62.83		
65HU 0102	148	63.38	8.08	18.13	73.79		
65HU 0103	145	16.23	25.14	26.17	48.69		
65HU 0105	199	18.97	5.11	23.95	70.94		
65HU 0107	188	8.10	0.63	19.53	79.84		
65HU 0110	203	1.82	2.55	28.24	69.21		
65HU 0112	203	48.94	22.25	15.57	62.18		
65HU 0114	192	0.13	4.52	7.82	87.66		
65HU 0117	185	1.73	5.45	15.42	79.13		
65HU 0118	35	60.67	11.47	48.46	40.07		
65HU 0122	119	24.76	4.23	27.88	67.89		
65HU 0124	174	0.10	0.95	22.34	76.71		
65HU 0126	161	16.53	4.19	10.49	85.32		
65HU 0128	190	46.83	5.60	2.99	91.41		
65HU 0130	163	0.07	5.22	24.43	70.35		
65HU 0132	155	1.51	5.01	34.85	60.14		
65HU 0134	106	3.86	59.79	14.32	25.89		
65HU 0136	90	67.08	59.90	13.12	26.98		
65HU 0138	119	68.73	18.84	41.13	40.03		
65HU 0140	139	42.66	10.92	36.12	52.96		
65HU 0142	77	33.26	41.91	26.04	32.05		
65HU 0144	71	11.69	80.19	12.40	7.41		
65HU 0145	72	18.81	41.74	27.74	30.52		
65HU 0146	62	21.43	74.21	15.97	9.82		
65HU 0147	71	0.59	72.21	17.77	10.02		
65HU 0149	64	77.75	56.00	21.93	22.07		
65HU 0151	71	66.93	56.45	23.23	20.32		
65HU 0153	81	67.46	42.66	31.53	25.81		
65HU 0155	66	14.42	42.97	29.35	27.68		
65HU 0157	79	63.69	23.35	39.00	37.65		
65HU 0159	81	25.66	42.25	35.42	22.33		
65HU 0161	75	65.10	42.81	30.03	27.16		
65HU 0163	64	61.04	47.02	24.26	28.72		
65HU 0165	60	67.64	25.45	27.96	46.87		
65HU 0168	36	26.18	83.12	11.43	5.45		
65HU 0170	190	1.54	23.39	36.67	39.94		
65HU 0172	207	50.14	3.09	42.22	54.69		
65HU 0174	203	58.16	3.30	7.29	89.41		
65HU 0175	126	83.86	25.46	47.46	27.08		
65HU 0177	128	4.55	7.59	55.42	36.99		
65HU 0179	119	52.87	12.79	61.49	25.72		
65HU 0181	119	63.42	11.78	63.64	24.58		
65HU 0183	126	43.41	30.82	39.00	30.18		
65HU 0184	71	75.87	17.54	46.62	35.84		
65HU 0186	91	90.99	10.43	40.07	49.50		
65HU 0188	97	83.98	16.92	33.71	49.31		
65HU 0190	113	84.38	19.08	35.15	45.77		
65HU 0192	99	77.94	30.83	32.86	36.31		
65HU 0194	90	84.84	7.65	49.27	44.98		
65HU 0196	88	85.41	25.70	38.86	35.44		
65HU 0198	117	91.59	28.42	46.73	24.85		
65HU 0200	123	75.48	36.59	37.86	25.55		
65HU 0202	155	73.53	6.45	51.55	42.00		
65HU 0204	225	77.47	8.43	45.63	45.94		
65HU 0206	276	2.14	1.43	20.88	77.69		
65HU 0207	214	37.59	22.30	43.87	33.83		
65HU 0208	236	3.75	4.94	50.93	44.13		
65HU 0212	285	8.68	5.94	43.87	50.19		
65HU 0214	276	27.79	4.36	44.99	49.95		
65HU 0216	185	65.04	50.09	17.31	32.60		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
65HU 0217	223	0.00	1.07	41.75	57.18		
65HU 0218	196	0.59	0.74	20.75	78.51		
65HU 0219	163	44.46	0.63	14.51	84.86		
65HU 0221	143	23.81	10.84	29.01	60.15		
65HU 0223	126	39.90	24.43	20.03	55.54		
65HU 0225	106	56.43	66.51	12.28	21.21		
65HU 0226	192	1.03	1.33	23.13	75.54		
65HU 0228	185	12.06	1.33	17.64	81.03		
65HU 0230	177	40.03	1.05	15.31	83.64		
65HU 0232	163	1.70	6.84	18.61	74.55		
65HU 0234	161	87.74	27.49	15.66	56.85		
65HU 0237	199	5.22	1.26	13.01	85.73		
65HU 0238	187	28.71	1.29	16.36	82.35		
65HU 0240	101	34.88	15.37	42.17	42.46		
65HU 0242	130	10.11	9.78	39.83	50.39		
65HU 0244	145	4.52	11.29	32.06	56.65		
65HU 0246	185	0.06	5.68	18.47	75.85		
65HU 0248	177	56.00	5.34	16.11	78.55		
65HU 0250	166	14.75	16.02	21.12	62.85		
65HU 0252	148	24.70	33.65	19.72	46.63		
65HU 0254	137	65.73	13.54	17.48	68.98		
65HU 0257	152	28.90	14.49	19.50	66.01		
65HU 0259	90	93.83	59.00	8.59	32.41		
65HU 0261	130	57.22	26.82	11.07	62.11		
65HU 0263	141	9.15	13.35	16.35	70.30		
65HU 0266	104	59.81	39.86	22.87	37.27		
65HU 0268	79	0.11	74.58	14.85	10.57		
65HU 0270	108	12.10	31.11	37.09	31.80		
65HU 0272	152	3.02	6.72	36.72	56.56		
65HU 0274	104	52.04	10.20	77.13	12.67		
65HU 0276	82	0.79	67.75	10.96	21.29		
65HU 0278	77	12.82	24.58	54.14	21.28		
65HU 0280	59	0.27	42.75	51.38	5.87		
65HU 0282	42	7.99	66.96	22.17	10.87		
65HU 0290	148	30.35	26.16	37.24	36.60		
65HU 0291	119	54.84	19.84	20.99	59.15		
65HU 0292	104	59.59	24.56	22.96	52.48		
65HU 0293	104	0.00	0.38	12.87	86.76		
65HU 0294	123	10.42	7.76	17.37	74.87		
65HU 0295	154	0.00	0.29	15.50	84.21		
65HU 0297	165	0.19	0.35	14.60	85.05		
65HU 0298	154	0.00	1.34	26.71	71.95		
65HU 0299	132	26.96	21.39	28.00	50.61		
65HU 0300	106	2.50	3.04	81.25	15.71		
65HU 0301	82	55.31	17.65	32.20	50.15		
65HU 0302	81	10.57	3.66	46.45	49.89		
65HU 0303	90	0.10	25.23	41.46	33.31		
65HU 0304	126	0.34	2.43	53.60	43.97		
65HU 0305	165	0.31	2.95	45.51	51.54		
65HU 0306	163	20.27	9.83	39.53	50.64		
65HU 0307	113	17.44	21.37	38.57	40.06		
65HU 0308	102	5.47	36.73	26.04	37.23		
65HU 0309	82	37.55	37.75	45.57	16.68		
65HU 0310	60	0.00	8.74	47.22	44.04		
65HU 0311	46	81.37	63.82	17.55	18.63		
65HU 0312	45	84.76	68.05	13.25	18.70		
65HU 0313	90	9.48	42.15	41.01	16.85		
65HU 0314	77	35.28	58.77	27.45	13.78		
65HU 0315	64	47.61	54.88	19.56	25.56		
65HU 0316	75	5.22	60.53	27.63	11.84		
65HU 0317	55	80.83	35.71	25.45	38.84		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
65HU 0318	66	72.57	21.51	33.98	44.51		
65HU 0319	101	35.30	0.31	47.40	52.29		
65HU 0320	128	41.72	11.84	43.75	44.41		
65HU 0321	152	34.57	9.48	49.13	41.39		
65HU 0322	137	1.95	4.71	58.89	36.40		
65HU 0323	95	26.38	6.75	53.17	40.08		
65HU 0324	70	1.64	14.54	41.15	44.31		
65HU 0325	59	1.37	19.02	52.80	28.18		
65HU 0326	42	0.00	11.29	38.00	50.71		
65HU 0327	71	0.56	4.62	50.68	44.70		
65HU 0328	66	18.53	8.57	43.88	47.55		
65HU 0329	70	0.80	8.42	51.85	39.73		
65HU 0330	82	0.29	1.46	33.51	65.03		
65TH 0028	176	4.57	23.26	39.16	37.58		
65TH 0028	176	4.57	23.26	39.16	37.58		
65TH 0030	199	1.24	22.08	46.32	31.60		
65TH 0031	214	0.21	13.65	51.19	35.21		
65TH 0033	219	2.00	40.03	29.47	30.50		
65TH 0036	110	36.23	56.67	25.17	18.16		
65TH 0038	70	50.63	15.70	49.48	34.82		
65TH 0041	140	8.03	33.64	41.22	25.14		
65TH 0044	165	14.05	35.17	42.84	21.99		
65TH 0046	179	4.29	7.33	54.37	38.30		
65TH 0051	384	0.00	2.07	53.13	44.80		
65TH 0053	230	4.94	2.97	30.29	66.75		
65TH 0055	225	0.10	2.52	34.36	63.12		
65TH 0057	230	0.00	1.30	26.17	72.53		
65TH 0059	180	4.87	1.30	33.87	64.83		
65TH 0061	195	0.00	1.18	52.24	46.58		
65TH 0064	195	7.18	7.57	83.07	9.35		
65TH 0065	205	23.86	48.08	36.18	15.73		
65TH 0066	157	10.74	17.98	59.52	22.50		
65TH 0067	161	5.91	18.23	58.60	22.91		
65TH 0071	135	12.62	26.32	42.09	31.59		
65TH 0073	132	9.95	10.66	60.98	28.36		
65TH 0075	128	0.38	8.05	53.37	38.58		
65TH 0077	126	2.36	8.03	55.78	36.19		
65TH 0078	138	22.75	62.95	22.39	14.65		
65TH 0080	108	16.34	15.36	54.01	30.59		
65TH 0082	115	11.79	54.73	31.94	13.34		
65TH 0084	130	11.87	13.37	54.78	31.85		
65TH 0086	143	0.00	2.36	73.23	24.41		
65TH 0088	130	0.18	3.70	77.22	19.08		
65TH 0090	113	11.47	27.08	51.74	21.18		
65TH 0092	95	18.70	49.09	32.10	18.81		
65TH 0094	87	28.34	54.47	32.65	12.88		
65TH 0095	50	4.05	64.53	23.41	12.06		
65TH 0099	76	36.18	44.00	52.76	3.23		
65TH 0101	84	23.57	20.89	47.71	31.49		
65TH 0103	95	9.79	35.67	39.81	24.52		
65TH 0105	98	27.30	63.56	21.13	15.31		
65TH 0105	98	4.40	45.58	41.17	13.24		
65TH 0105	98	10.70	44.48	40.22	15.28		
65TH 0105	98	1.70	44.49	40.22	15.29		
65TH 0107	92	9.62	39.23	50.25	10.50		
65TH 0109	102	2.44	46.75	46.62	6.63		
65TH 0109	102	2.44	46.74	46.63	6.63		
65TH 0111	88	0.00	52.84	39.13	8.02		
65TH 0113	106	10.13	38.52	55.65	5.82		
65TH 0117	117	0.00	4.55	74.69	20.76		
65TH 0119	128	2.44	12.24	57.59	30.16		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
65TH 0120	122	8.58	12.13	59.06	28.81		
65TH 0123	101	3.53	15.12	61.74	23.25		
65TH 0125	104	4.08	16.66	53.59	29.75		
65TH 0130	62	48.81	50.52	41.10	8.38		
65TH 0132	77	7.67	16.46	52.02	31.52		
65TH 0133	77	4.09	15.73	52.62	31.65		
65TH 0134	75	21.84	9.21	60.35	30.44		
65TH 0136	62	89.31	60.89	30.78	8.33		
65TH 0137	70	10.02	54.99	39.32	5.69		
65TH 0138	132	21.20	46.60	31.81	21.59		
65TH 0139	81	55.19	73.60	22.38	4.07		
65TH 0143	88	94.95	38.02	49.11	12.87		
65TH 0145	102	0.10	15.91	54.56	29.53		
65TH 0146	102	5.00	24.48	44.57	30.95		
65TH 0148	110	5.45	16.00	48.81	35.19		
65TH 0149	188	0.93	10.99	61.34	27.66		
65TH 0150	137	0.00	2.29	47.65	50.06		
65TH 0151	130	0.00	2.60	49.23	48.17		
65TH 0152	128	10.72	38.09	29.80	32.09		
65TH 0154	164	0.13	2.12	16.83	81.05		
65TH 0156	174	2.73	9.23	85.65	5.06		
65TH 0157	195	65.86	23.73	30.05	46.72		
65TH 0159	198	0.00	1.84	73.21	24.94		
65TH 0161	200	0.91	14.90	48.25	36.85		
65TH 0163	209	0.23	9.69	26.68	63.63		
65TH 0164	200	0.00	13.34	40.90	45.76		
65TH 0165	195	0.00	10.95	32.05	57.00		
65TH 0166	197	0.00	1.83	32.64	65.54		
65TH 0170	175	0.00	2.90	62.47	34.63		
65TH 0171	197	30.34	20.46	39.00	40.53		
65TH 0174	164	5.39	15.40	61.12	23.46		
65TH 0174	164	5.18	64.30	29.77	5.93		
65TH 0178	170	0.00	6.27	64.25	29.48		
65TH 0180	170	2.29	9.90	69.57	20.53		
65TH 0180	170	4.54	14.26	71.73	14.01		
65TH 0185	132	11.58	38.97	47.43	13.60		
65TH 0186	102	17.60	59.81	28.79	11.40		
65TH 0187	155	7.22	5.32	71.98	22.70		
65TH 0189	126	17.91	25.76	56.83	17.41		
65TH 0191	106	16.70	39.60	47.61	12.79		
65TH 0192	70	0.00	1.81	79.57	18.62		
65TH 0193	113	6.21	46.17	37.90	15.93		
65TH 0201	44	45.87	94.90	3.45	1.65		
65TH 0205	81	91.63	66.67	21.74	11.59		
65TH 0206	86	48.74	52.39	33.71	13.90		
65TH 0207	98	42.26	63.16	26.65	10.19		
65TH 0209	89	40.75	69.38	22.38	8.24		
65TH 0210	89	53.93	66.75	22.75	10.50		
65TH 0211	66	0.26	66.09	25.47	8.44		
65TH 0212	50	0.29	26.70	57.49	15.81		
65TH 0213	55	13.85	61.85	28.06	10.09		
65TH 0214	65	48.98	60.68	29.87	9.45		
65TH 0215	54	39.91	51.44	33.08	15.48		
65TH 0216	51	34.33	78.54	16.16	5.30		
65TH 0217	50	27.45	84.57	11.53	3.90		
65TH 0218	55	42.42	60.66	28.87	10.47		
65TH 0220	66	0.00	24.54	32.14	43.32		
65TH 0220	66	0.04	14.16	23.25	62.59		
65TH 0222	128	18.44	40.78	51.30	7.92		
65TH 0223	166	48.08	13.78	78.02	8.20		
65TH 0223	166	48.08	13.78	78.02	8.20		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
65TH 0224	164	10.66	20.11	60.83	19.06		
65TH 0226	154	0.00	8.15	60.90	30.95		
65TH 0226	154	2.76	7.42	82.28	10.30		
65TH 0228	163	0.00	17.95	31.75	50.30		
65TH 0228	163	8.52	12.73	21.56	65.71		
65TH 0228	163	7.17	16.63	55.09	28.28		
65TH 0229	178	0.17	0.50	64.89	34.61		
65TH 0230	200	0.00	6.74	40.43	52.83		
65TH 0230	200	0.26	4.73	53.40	41.87		
65TH 0231	163	9.29	14.93	51.78	33.37		
65TH 0232	201	0.00	9.17	38.09	52.74		
65TH 0232	201	0.26	5.04	19.85	71.11		
65TH 0234	210	0.00	11.45	44.88	43.67		
65TH 0234	210	1.02	10.43	19.67	69.90		
65TH 0235A	215	0.61	3.70	50.26	46.04		
65TH 0235B	215	0.68	1.28	58.02	40.70		
65TH 0236	216	0.00	13.63	40.61	45.76		
65TH 0236	216	2.20	12.10	37.15	50.75		
65TH 0237	212	0.09	1.50	18.74	79.76		
65TH 0237	163(?)	0.00	0.69	75.71	23.60		
65TH 0238	210	0.20	6.60	34.43	58.97		
65TH 0238	210	0.00	3.20	27.47	69.33		
65TH 0244	180	0.00	6.48	53.05	40.47		
65TH 0244	180	3.79	5.66	47.66	46.67		
65TH 0244	180	0.64	8.46	50.88	40.66		
65TH 0245	144	11.49	13.58	25.30	61.12		
65TH 0246	130	13.65	26.25	37.32	36.43		
65TH 0247	130	2.23	24.00	47.42	28.58		
65TH 0250	154	0.23	11.70	57.58	30.72		
65TH 0252	135	0.00	26.83	38.06	35.11		
65TH 0252	135	6.58	14.34	53.48	32.18		
65TH 0254	190	31.61	33.79	36.78	29.43		
65TH 0254	190	4.95	20.37	27.93	51.70		
65TH 0257	165	9.22	23.78	32.52	43.70		
65TH 0258	140	11.35	31.40	27.65	40.95		
65TH 0259	165	8.50	23.22	27.99	48.79		
65TH 0260	152	0.03	20.71	33.34	45.95		
65TH 0260	152	10.75	19.06	24.86	56.08		
65TH 0261	154	0.53	10.27	33.15	56.58		
65TH 0263	118	0.09	5.24	34.02	60.74		
65TH 0264	122	0.00	35.05	25.87	39.08		
65TH 0264	122	9.28	32.83	17.83	49.34		
65TH 0265	123	7.56	14.81	28.82	56.37		
65TH 0266	144	25.54	24.83	29.67	44.50		
65TH 0267	162	0.11	0.88	43.40	55.72		
65TH 0268	155	0.00	70.60	20.19	9.21		
65TH 0268	155	59.04	86.40	10.30	3.32		
65TH 0269	150	0.30	0.79	51.91	47.30		
65TH 0271	155	0.17	2.44	33.20	64.36		
65TH 0272A	143	0.00	16.22	34.67	49.11		
65TH 0272B	143	0.00	1.78	49.32	48.90		
65TH 0272	143	2.41	10.55	31.69	57.76		
65TH 0273	130	0.00	3.39	42.75	53.86		
65TH 0273	130	0.00	0.38	42.70	56.92		
65TH 0274	128	0.00	13.44	39.77	46.79		
65TH 0274	128	0.00	4.46	34.23	61.31		
65TH 0275	141	0.42	10.30	27.78	61.92		
65TH 0277	160	5.59	19.64	27.55	52.81		
65TH 0279	170	0.00	0.73	72.98	26.29		
65TH 0280	140	0.00	6.99	43.48	49.53		
65TH 0280	140	0.00	0.27	50.55	49.18		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
65TH 0281	112	22.96	65.26	18.04	16.70		
65TH 0282	159	0.00	7.36	31.69	60.95		
65TH 0282	159	0.00	0.56	38.92	60.52		
65TH 0284	143	0.00	9.44	33.83	56.73		
65TH 0284	143	1.46	10.18	37.38	52.44		
65TH 0285	135	0.00	0.73	27.52	71.75		
65TH 0286	130	0.00	1.03	32.35	66.62		
65TH 0286	130	0.00	2.15	64.12	33.73		
65TH 0287	165	14.20	30.62	63.58	5.80		
65TH 0288	148	0.00	33.19	29.23	37.58		
65TH 0288	148	11.51	35.08	34.67	30.25		
65TH 0289	176	19.64	27.91	33.21	38.88		
65TH 0290	200	8.37	29.30	68.95	1.75		
65TH 0291	180	3.26	17.93	32.22	49.85		
65TH 0292	255	0.92	1.37	27.06	71.56		
65TH 0293	155	5.87	7.38	48.04	44.58		
65TH 0295	113	7.99	14.15	51.52	34.33		
65TH 0296	137	3.99	21.67	48.69	29.63		
65TH 0297	150	0.72	21.07	37.37	41.56		
65TH 0299	150	8.68	43.31	31.98	24.71		
65TH 0300	121	7.70	38.74	32.34	28.92		
65TH 0301	139	7.14	5.49	52.28	42.24		
65TH 0302	155	0.00	3.49	34.74	61.77		
65TH 0302	155	0.15	4.02	29.08	66.90		
65TH 0303	126	2.92	7.01	39.07	53.92		
65TH 0304	199	0.00	1.45	43.82	54.73		
65TH 0317	118	0.74	13.20	60.46	26.34		
65TH 0320	106	7.64	21.38	57.36	21.26		
65TH 0321	106	4.44	25.09	58.06	16.85		
65TH 0323	46	46.29	84.36	9.67	5.95		
65TH 0324	113	0.28	9.35	56.97	33.68		
65TH 0325	124	0.00	5.96	55.40	38.65		
65TH 0326	140	0.92	1.58	61.89	36.53		
65TH 0327	123	0.00	4.21	53.40	42.38		
65TH 0328	132	0.00	9.06	65.16	25.78		
65TH 0328	132	1.51	9.08	50.08	40.84		
65TH 0330	101	8.37	12.35	54.72	32.93		
65TH 0332	123	0.00	6.56	71.20	22.24		
65TH 0332	123	0.38	8.14	63.42	28.44		
65TH 0333	135	1.84	13.68	46.90	39.42		
65TH 0335	155	0.00	1.15	42.88	55.97		
65TH 0336	157	0.15	1.06	41.41	57.53		
65TH 0337	166	0.00	2.62	26.84	70.54		
65TH 0338	134	16.65	36.40	36.75	26.62		
65TH 0339	137	35.95	24.89	57.18	17.93		
65TH 0340	150	1.00	12.77	39.15	48.08		
65TH 0341	157	0.48	4.78	48.17	47.05		
65TH 0342	146	19.01	28.68	27.82	43.50		
65TH 0343	163	0.67	8.58	58.83	32.59		
65TH 0344	161	7.05	16.08	52.33	31.60		
65TH 0345	172	0.00	1.47	69.30	29.23		
65TH 0346	149	0.35	9.50	84.30	6.20		
65TH 0347	161	1.68	22.12	40.39	37.49		
65TH 0348	155	0.48	18.80	55.34	25.85		
65TH 0349	176	2.97	15.85	37.10	47.05		
65TH 0350	192	0.00	0.66	56.37	42.97		
65TH 0351	194	2.26	0.59	42.39	57.02		
65TH 0352	201	1.44	21.59	14.71	63.70		
65TH 0353	205	0.10	1.78	24.90	73.32		
65TH 0354	212	4.12	12.34	30.11	57.55		
65TH 0355	207	0.54	13.54	23.98	62.48		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
65TH 0356	220	2.11	4.20	63.90	31.90		
65TH 0357	190	0.09	8.99	78.98	12.03		
65TH 0358	201	3.46	2.09	16.91	81.00		
65TH 0359	180	0.00	3.22	25.62	71.16		
65TH 0360	180	0.00	0.84	69.27	29.89		
65TH 0361	180	0.40	2.74	72.51	24.75		
65TH 0362	183	0.14	2.26	81.99	15.75		
65TH 0363	184	0.00	4.10	67.09	28.81		
65TH 0365	180	9.66	32.16	40.68	27.16		
65TH 0366	249	0.20	1.26	80.75	17.99		
65TH 0367	220	0.10	1.53	35.66	62.81		
65TH 0368	223	3.09	3.78	18.97	77.26		
65TH 0369	221	0.00	2.08	36.30	61.62		
65TH 0369	221	0.14	0.81	27.13	72.06		
65TH 0370	220	1.46	2.21	30.53	67.26		
65TH 0371	220	10.54	34.77	50.78	14.45		
65TH 0375	124	31.78	40.19	52.25	7.56		
65TH 0377	123	25.17	37.64	53.85	8.51		
65TH 0378	113	22.36	37.60	45.88	16.52		
65TH 0379	113	20.06	23.79	55.59	20.62		
65TH 0380	100	39.80	44.20	45.25	10.55		
65TH 0381	110	30.59	53.84	37.76	8.43		
65TH 0382	118	20.30	31.42	48.20	20.38		
65TH 0383	126	12.18	33.46	44.45	22.09		
65TH 0385	128	18.58	20.60	67.83	11.57		
65TH 0386	124	12.53	32.78	59.53	7.69		
65TH 0389	124	41.41	17.50	61.10	21.40		
65TH 0389	124	7.13	37.60	40.00	22.40		
65TH 0391	128	0.00	73.54	21.10	5.36		
65TH 0391	128	67.24	62.29	29.83	7.88		
65TH 0395	146	29.98	53.43	29.78	16.79		
65TH 0396	160	43.79	41.17	33.09	25.74		
65TH 0398	223	41.60	12.36	52.83	34.81		
65TH 0400	263	8.39	35.25	45.85	18.90		
65TH 0402	205	0.00	6.09	71.45	22.47		
65TH 0403	225	2.13	27.67	46.96	25.37		
65TH 0405	167	30.97	31.90	44.50	23.60		
65TH 0406	137	0.22	6.32	40.70	52.98		
65TH 0407	143	12.96	6.53	30.89	62.58		
65TH 0408	148	0.00	2.43	58.98	38.51		
65TH 0408	148	0.60	0.58	37.20	62.22		
65TH 0409	161	0.13	0.33	22.60	77.07		
65TH 0410	181	0.22	1.39	62.75	35.86		
65TH 0411	183	37.43	0.79	58.49	40.72		
65TH 0412	185	10.20	1.66	65.17	33.17		
65TH 0418	229	0.21	0.28	34.41	65.31		
65TH 0419	219	1.09	10.48	65.87	23.65		
65TH 0420	227	0.54	3.07	66.64	30.29		
65TH 0421	209	10.23	19.83	39.30	40.87		
65TH 0422	135	60.35	46.46	34.65	18.89		
65TH 0424	139	27.84	44.05	34.45	21.50		
65TH 0426	229	0.24	13.33	63.38	23.29		
65TH 0427	229	0.04	2.14	94.50	3.36		
65TH 0429	216	0.73	3.52	50.73	45.75		
65TH 0433	110	4.64	4.75	56.52	38.73		
65TH 0434	190	11.59	13.54	52.17	34.29		
65TH 0436	215	0.00	0.89	62.71	36.40		
65TH 0436	215	0.00	1.42	47.38	51.20		
65TH 0437	205	0.27	2.03	52.73	45.24		
65TH 0438	210	1.04	3.82	47.15	49.03		
65TH 0439	219	15.28	3.90	18.72	77.38		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
65TH 0440		0.05	18.77	40.40	40.83		
65TH 0443	183	1.65	9.41	61.64	28.95		
65TH 0444		0.00	16.81	41.32	41.87		
65TH 0448		0.00	0.27	37.92	61.82		
65TH 0452		0.00	54.79	26.63	18.58		
65TH 0454		0.00	50.37	30.16	19.47		
65TH 0456		0.00	60.90	23.63	15.47		
65TH 0458		0.00	7.51	34.58	57.91		
65TH 0462	150	14.29	35.96	23.33	40.71		
65TH 0465	132	0.68	9.76	23.00	67.24		
65TH 0466		0.00	5.15	31.40	63.45		
65TH 0468		0.00	6.04	42.54	51.42		
65TH 0470	165	0.00	0.51	31.65	67.83		
65TH 0474		0.00	2.98	33.28	63.74		
65TH 0476		0.01	38.12	41.93	19.95		
65TH 0479	128	17.65	15.26	49.05	35.69		
65TH 0480		0.00	1.35	53.64	45.01		
65TH 0481		0.00	4.45	61.96	33.59		
65TH 0482	159	3.14	2.61	44.81	52.58		
65TH 0483	135	0.00	0.22	62.66	37.11		
65TH 0484		0.09	4.06	51.81	44.13		
65TH 0486	167	7.56	22.36	34.13	43.51		
65TH 0488		0.00	0.50	51.45	48.05		
65TH 0490		0.00	27.33	45.72	26.95		
65TH 0491	157	3.88	14.47	58.07	27.46		
65TH 0493	81	40.87	69.28	17.61	13.11		
65TH 0494	83	31.62	30.46	43.07	26.47		
65TH 0496		0.00	53.92	33.93	12.15		
65TH 0497	73	2.77	75.61	15.87	8.52		
65TH 0499	64	57.96	48.29	26.66	25.05		
65TH 0501	73	29.28	49.55	32.55	17.90		
65TH 0502	55	62.29	63.54	21.96	14.50		
65TH 0503	48	40.99	57.32	27.65	15.03		
65TH 0504		0.02	32.92	44.45	22.63		
65TH 0505	70	17.69	37.01	40.97	22.02		
65TH 0506	73	28.68	66.17	25.14	8.69		
65TH 0507	77	43.21	48.78	37.28	13.94		
65TH 0508	84	31.18	44.22	49.58	6.20		
65TH 0509	93	9.05	28.59	49.05	22.36		
65TH 0510	117	1.80	9.85	65.23	24.92		
65TH 0512		0.09	63.18	25.51	11.32		
65TH 0513	62	52.75	71.03	17.69	11.28		
65TH 0514	51	12.11	65.19	20.95	13.86		
65TH 0516	73	3.00	18.41	71.42	10.17		
65TH 0520	128	33.03	42.17	44.14	13.69		
65TH 0523	177	9.00	4.47	74.39	21.14		
65TH 0529	109	42.46	25.47	52.44	22.09		
65TH 0532	141	27.44	31.92	48.80	19.28		
65TH 0538	165	8.51	2.69	65.68	31.63		
65TH 0544	185	0.80	31.40	46.10	22.50		
65TH 0547	205	0.43	2.09	61.03	36.88		
65TH 0548	212	2.95	0.42	47.09	52.49		
65TH 0550	194	0.00	0.55	43.28	56.17		
65TH 0553	135	3.49	17.16	32.62	50.22		
65TH 0555	99	5.07	26.37	54.44	19.19		
65TH 0560	137	0.24	5.15	47.88	46.97		
65TH 0563	113	0.00	1.17	68.33	30.50		
65TH 0566	104	49.47	34.36	20.98	44.66		
65TH 0575	502	0.00	5.84	58.99	35.17		
65TH 0577	388	0.00	2.16	81.79	16.05		
65TH 0579	438	0.69	28.64	48.39	22.97		

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
65TH 0582	378	0.00	9.72	66.44	23.84		
71MLA0001	60	61.15	23.45	45.85	30.70	4.83	3.40
71MLA0002	82	26.22	21.62	48.86	29.48	5.36	2.88
71MLA0003	104	45.46	25.23	43.13	31.64	5.47	3.33
71MLA0004	117	40.01	11.96	52.34	35.70	6.42	2.37
71MLB0001	119	8.59	19.18	60.77	20.05	5.51	2.17
71MLB0002	124	22.99	30.84	46.92	22.24	5.15	2.87
71MLB0003	104	17.57	32.92	45.56	21.52	4.64	3.23
71MLC0001	51	12.82	38.25	46.56	15.19	4.62	2.14
71MLC0002	110	12.91	23.31	60.28	16.41	4.75	2.38
71MLC0004	130	22.44	52.14	30.35	17.51	3.53	3.76
71MLC0006	167	4.63	0.66	60.43	38.91	7.47	2.53
71MLD0002	140	19.55	46.34	32.45	21.21	4.54	3.39
71MLD0003	124	18.44	47.29	28.06	24.65	4.68	3.99
71MLD0004	115	0.00	11.64	54.18	34.18	6.77	2.85
71MLD0005	126	0.00	4.78	73.38	21.84	6.32	2.10
71MLD0006	62	3.12	49.34	36.48	14.18	4.26	2.12
71MLE0001	82	0.24	41.95	47.48	10.57	4.00	1.35
71MLE0002	120	0.20	0.95	73.76	25.29	6.93	2.31
71MLF0002	115	0.24	5.88	60.29	33.83	7.22	3.07
71MLF0004	133	2.27	14.63	48.79	36.58	7.16	3.48
71MLF0006	130	0.83	13.03	48.11	38.86	-	-
71MLF0007	130	0.13	2.17	50.00	47.83	-	-
71MLF0009	120	25.88	26.56	33.37	40.07	5.73	5.15
71MLG0001	146	4.12	79.62	9.58	10.80	2.99	2.12
71MLG0002	175	1.19	19.98	25.06	54.96	-	-
71MLG0003		0.45	12.27	28.67	59.06	-	-
71MLG0004	150	0.53	24.98	36.01	39.01	6.55	3.95
71MLG0005	150	0.00	58.89	25.94	15.17	4.09	2.63
71MLG0006	150	0.00	1.84	25.78	72.38	-	-
71MLH0001	177	0.41	7.74	30.86	61.40	-	-
71MLH0002	177	2.18	18.70	30.98	50.32	-	-
71MLH0003	125	6.06	46.85	31.31	21.84	5.14	3.73
71MLH0004		8.18	48.13	21.79	30.08	5.25	4.37
71MLH0005	135	0.26	4.40	48.90	76.70	7.87	3.03
71MLH0006	95	17.84	32.94	47.52	19.54	4.77	3.18
71MLH0008	87	1.86	46.80	39.34	13.86	4.20	2.11
71MLH0009	44	18.31	69.06	19.07	11.87	3.29	2.55
71MLH0010	32	49.36	89.98	4.55	5.47	0.75	1.47
71MLI0002	65	1.17	55.80	29.21	14.99	4.28	2.47
71MLI0003	65	2.67	64.37	25.78	9.85	3.44	1.61
71MLI0004	80	12.39	31.27	41.96	26.77	5.34	3.88
71MLI0006	78	15.81	47.94	28.52	23.54	4.82	4.03
71MLI0007	130	0.00	18.51	56.98	24.51	6.17	2.77
71MLI0008	140	0.00	1.26	61.19	37.55	7.54	2.92
71MLJ0001	53	20.84	51.64	27.09	21.27	3.94	4.24
71MLJ0002	50	3.67	95.25	2.39	2.36	1.97	0.72
71MLJ0004	57	49.35	77.84	11.45	10.71	-	-
71MLJ0006	120	0.10	12.85	53.38	33.77	7.08	3.39
71MLJ0007	160	0.51	8.43	55.51	36.06	7.22	2.93
71MLK0002	105	0.00	0.45	61.87	37.68	7.71	2.98
71MLK0003		0.00	4.35	57.39	38.26	7.75	3.01
71MLK0004	118	1.85	58.28	22.20	19.52	4.50	3.51
71MLK0005	85	24.21	55.56	17.42	27.02	4.46	5.10
71MLL0001	85	0.00	3.97	48.65	47.38	-	-
71MLL0002	78	3.33	15.28	53.14	31.58	7.09	3.53
71MLL0004	126	15.42	31.75	18.18	50.07	-	-
71MLL0005	105	9.53	63.17	13.71	23.12	4.46	4.39
71MLL0006	165	0.00	7.27	30.98	61.75	-	-
71MLL0008	177	0.00	3.92	36.25	59.83	-	-
71MLL0009	135	7.79	18.89	48.86	32.25	6.69	3.61

Sample No.	Depth (m)	>2 mm %	Sand %	Silt %	Clay %	Mean (phi)	Sorting
71MLN0001	85	16.88	76.98	14.21	8.81	2.54	2.33
71MLN0003	98	0.85	13.92	56.84	29.24	6.47	2.85
71MLN0004	95	12.93	46.98	31.48	21.54	4.26	3.80
71MLN0001	155	3.26	15.32	25.96	58.72	-	-
71MLN0002	200	4.41	22.51	32.34	45.15	-	-
71MLN0003	180	0.00	1.76	22.57	75.67	-	-
71MLN0004	118	2.42	23.21	24.19	52.60	-	-
71MLN0005	100	10.76	54.36	17.94	27.70	5.15	4.29
71MLN0006	110	0.49	14.58	28.04	57.38	-	-
71MLN0007	105	0.00	0.10	32.33	67.57	-	-
84GMB0001	178	0.0	3.00	32.70	64.30	-	-
84GMC0001	165	0.0	1.30	47.00	51.70	-	-
84GMB0002	170	0.7	3.70	34.50	61.80	-	-
84ICG0001	198	0.5	7.60	41.70	50.70	-	-
84ICG0002	176	5.7	2.30	33.60	64.10	-	-
84ICG0003	188	0.0	1.70	37.00	61.30	-	-
86HU 0002	201	6.2	14.31	38.45	47.24	-	-
86HU 0004	179	8.9	4.52	32.74	62.74	-	-

APPENDIX D

APPEMAP PROGRAM: Plotting Method for Grain-size Data

The Appmap programs (Ellwood, 1981) are designed for data contouring using moving average techniques which consider weighting functions based on distance and sample density. In general, a grid is established and estimated values are assigned to center points of cells within the grid. The sample locations on which the estimates are based are scattered throughout the map area, so that the number of sites per cell may vary from several to none. Estimated values for each grid point were calculated systematically from all data points within a cell and adjacent cells (up to 5) through weighting of values inversely according to distance, thus smoothing the data. Large areas void of samples receive a minimal contour value, but the data display only represents a spot image, 50km diameter, of areas where grid cell values are calculated. This limits extrapolation of data to large areas without sample control.

In considering the distribution of gravel within Hudson Bay, a minimum value of 0.001% was given to those sample sites lacking a gravel fraction. Within the Appmap programs, zero values are disregarded, but the presence or absence of gravel within a sample is considered significant, therefore, a minimum value is necessary to indicate a sample location.

APPENDIX E

Lithologic Analyses, Hudson Bay Surficial Sediments

A. Description of Major Lithologic Groups

- 1) Grey carbonate: light grey to grey to buff limestone and dolomite varying from microcrystalline to sucrosic texture, may be fossiliferous.
- 2) Pink/Red carbonate: pink to red to reddish brown calcareous mudstone, siltstone and minor sandstone, may be fossiliferous.
- 3) Other Paleozoic: red-brown, brown, grey, grey-green shale, siltstone, sandstone, generally non-calcareous, soft (could possibly be unmetamorphosed Proterozoic sediments) (limited occurrence).
- 4) Crystalline: includes all coarse crystalline plutonic and metamorphic rocks, schists, amphibolites, felsic volcanics, clean, angular quartz.
- 5) Dubawnt: purple and maroon volcanic rocks, kaolin and hematite cemented orthoquartzite, hematite coated quartz, hematite-rich arkosic sandstones (less frequently)
- 6) Greywacke/Argillite: dark grey to grey-green greywacke, and dark grey, generally hard, shale, clastic texture visible.
- 7) Quartz: rounded, pitted, frosted, interpreted as multi-cycle quartz, probable derived from Proterozoic sediment.
- 8) Other Proterozoic: includes basaltic volcanics characteristic of the Proterozoic basins of eastern Hudson Bay, iron formation, chert, other metasediments including orthoquartzite and arkose (other than Dubawnt), red and grey argillite. (some of these sediments may be Paleozoic)

B. Results of Lithologic Analyses

Size Fraction: 2.0 - 5.6mm

Results recorded as percentage by weight of granule fraction

Total sample no.: 213

Sample No.	Total	Grey	Pink	Other	Total		Quartz	Greywacke/ Argillite	Other Proterozoic
	Sample				Crystalline	Dubawnt			
	Weight	Carbonate	Carbonate	Paleozoic					
61HU 0005	1.80	94.40	0.00	0.00	5.60	0.00	0.00	0.00	0.00
61HU 0011	4.40	63.00	0.00	2.20	33.40	0.00	0.00	1.10	0.20
61HU 0015	2.20	98.60	0.00	0.00	1.40	0.00	0.00	0.00	0.00
61HU 0024	17.60	3.40	0.00	0.00	89.30	2.90	0.00	2.50	1.90
61HU 0040	1.80	0.00	0.00	0.00	98.40	0.00	0.00	0.00	1.60
61HU 0051	2.40	2.90	0.00	1.20	60.20	0.00	0.00	35.70	0.00
61HU 0060	16.00	61.20	1.10	2.00	27.40	2.40	0.00	0.90	5.00
61HU 0063	2.90	53.50	0.00	0.00	34.00	2.80	0.00	9.40	0.40
61HU 0064	1.60	52.30	0.70	0.70	40.60	0.00	1.30	3.20	1.30
61HU 0066	0.80	26.60	0.00	0.00	73.50	0.00	0.00	0.00	0.00
61HU 0069	7.10	36.10	1.60	0.00	61.80	0.00	0.00	0.00	0.60
61HU 0073	1.20	45.20	0.00	0.00	48.70	4.40	0.00	1.70	0.00
61HU 0076	2.00	50.30	0.00	1.00	38.20	5.00	0.00	0.00	5.50
61HU 0088	4.10	0.00	0.00	0.00	28.70	0.00	0.00	71.30	0.00
61HU 0089	11.50	0.80	0.00	0.00	56.10	0.00	0.00	42.10	1.00
61HU 0102	9.70	7.90	0.00	0.10	34.80	0.00	0.00	47.20	10.00
61HU 0103	1.30	75.20	3.00	0.00	19.60	0.00	0.00	1.50	0.80
61HU 0110	2.30	6.40	0.00	0.00	41.90	0.00	0.00	48.70	3.00
61HU 0118	1.90	62.90	5.70	0.00	16.50	0.00	0.00	13.90	1.00
61HU 0123	0.80	56.60	0.00	0.00	19.70	0.00	0.00	21.10	2.60
61HU 0125	0.30	46.70	10.00	0.00	30.00	0.00	0.00	10.00	3.30
61HU 0148	10.10	89.20	2.00	0.00	7.80	0.00	0.20	0.80	0.00
61HU 0161	3.80	91.10	0.00	6.00	2.90	0.00	0.00	0.00	0.00
61HU 0169	3.40	4.70	0.00	0.00	95.30	0.00	0.00	0.00	0.00
61HU 0194	1.50	27.50	0.00	0.00	20.30	0.00	0.00	40.50	11.80
61HU 0207	1.40	3.50	0.00	0.00	18.30	0.00	0.00	28.90	49.30
61HU 0210	1.60	1.90	0.00	0.00	23.70	0.00	1.30	71.90	1.30
61HU 0216	1.30	30.80	0.00	0.00	20.30	0.00	0.00	47.30	1.50
61HU 0218	0.80	43.20	1.20	0.00	34.60	0.00	0.00	21.00	0.00
61HU 0223	0.90	45.70	0.00	0.00	51.10	0.00	0.00	3.20	0.00
61HU 0225	4.40	68.90	0.00	0.00	24.80	0.00	0.00	6.40	0.00
61HU 0226	8.10	86.70	0.10	0.00	12.40	0.00	0.00	0.00	0.80
65HU 0029	10.50	0.30	6.90	74.90	8.10	3.90	0.20	0.00	5.80
65HU 0073	31.80	3.60	2.10	75.00	9.70	0.50	0.00	0.90	8.20
65HU 0084	18.90	0.00	0.00	69.00	17.30	0.00	1.30	3.50	9.00
65HU 0101	3.20	80.40	4.40	0.00	12.00	0.00	0.00	1.90	0.90
65HU 0102	1.40	49.60	4.40	0.00	43.80	0.00	0.70	0.00	1.50
65HU 0107	1.50	45.90	0.00	0.00	51.40	2.70	0.00	0.00	0.00
65HU 0122	0.70	77.30	0.00	0.00	22.70	0.00	0.00	0.00	0.00
65HU 0142	87.70	53.70	1.00	0.00	32.10	0.50	0.70	10.20	1.80
65HU 0146	19.00	57.70	0.70	0.00	31.30	0.40	1.10	5.90	2.90
65HU 0149	35.90	54.60	3.00	0.20	35.40	1.80	0.60	3.60	0.90
65HU 0151	35.10	54.80	2.00	0.10	27.40	0.70	0.10	11.40	3.50
65HU 0153	37.50	44.50	2.00	0.30	34.60	0.80	0.70	13.30	4.10
65HU 0155	16.00	60.90	1.00	0.00	20.90	0.70	0.10	10.90	5.60
65HU 0157	14.80	55.30	1.20	0.00	25.80	0.00	0.80	13.30	3.70
65HU 0159	14.80	33.10	0.40	0.00	47.00	2.00	1.50	11.10	4.90
65HU 0161	27.80	44.50	2.10	0.00	44.40	0.50	1.30	5.30	1.90
65HU 0165	28.60	28.20	0.30	0.00	34.00	1.50	0.70	31.50	3.90
65HU 0170	13.10	61.30	0.60	0.00	26.30	0.80	0.20	10.40	0.30
65HU 0172	2.60	72.40	1.10	0.00	23.50	0.00	0.00	1.50	1.50
65HU 0174	1.00	92.30	0.00	0.00	7.70	0.00	0.00	0.00	0.00
65HU 0175	12.80	79.80	0.00	0.00	15.70	1.30	0.00	0.20	3.00
65HU 0181	4.90	95.90	0.00	0.00	4.10	0.00	0.00	0.00	0.00

Sample No.	Total Sample Weight	Grey Carbonate	Pink Carbonate	Other Paleozoic	Total Crystalline	Dubawnt	Quartz	Greywacke/Argillite	Other Proterozoic
65HU 0183	5.30	89.00	1.80	1.00	8.20	0.00	0.00	0.00	0.00
65HU 0184	23.70	92.40	0.10	0.00	6.50	0.30	0.20	0.50	0.00
65HU 0186	9.50	91.90	0.00	0.00	8.10	0.00	0.00	0.00	0.00
65HU 0188	29.90	98.40	0.00	0.00	1.60	0.00	0.00	0.00	0.00
65HU 0190	10.70	96.90	0.10	0.00	3.00	0.00	0.00	0.00	0.00
65HU 0192	19.50	99.10	0.30	0.00	0.70	0.00	0.05	0.00	0.00
65HU 0196	23.01	96.50	0.30	0.10	3.00	0.00	0.00	0.00	0.00
65HU 0198	3.00	96.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00
65HU 0204	4.40	91.80	0.70	0.00	7.60	0.00	0.00	0.00	0.00
65TH 0036	11.40	70.00	2.40	0.00	15.00	0.30	0.10	12.30	0.00
65TH 0038	8.30	89.30	1.20	0.00	8.00	0.00	0.10	0.20	1.20
65TH 0042	0.10	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65TH 0055	0.50	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65TH 0064	1.80	55.10	2.30	0.00	42.60	0.00	0.00	0.00	0.00
65TH 0066	6.60	52.40	0.50	0.00	42.80	1.50	0.00	1.10	1.80
65TH 0080	0.90	50.50	0.00	0.00	37.90	4.20	0.00	0.00	7.40
65TH 0082	34.70	13.30	0.10	0.00	81.90	3.90	0.20	0.00	0.60
65TH 0084	4.00	39.80	0.00	0.00	53.80	6.50	0.00	0.00	0.00
65TH 0090	24.50	12.00	0.10	0.00	82.00	4.80	0.50	0.00	0.60
65TH 0092	5.30	4.30	0.00	0.00	89.20	6.40	0.00	0.00	0.00
65TH 0120	7.50	59.50	0.00	0.00	31.40	7.10	0.00	0.00	2.00
65TH 0130	32.20	74.10	0.80	0.00	22.50	1.50	0.00	1.20	0.00
65TH 0132	18.70	63.60	0.00	0.00	31.20	1.60	0.10	3.20	0.40
65TH 0137	17.90	18.20	0.00	0.80	76.30	0.00	0.10	1.70	2.90
65TH 0138	47.90	59.00	2.60	0.30	34.40	0.90	0.02	2.00	0.90
65TH 0152	13.10	53.60	5.70	1.20	20.40	0.20	0.00	11.90	7.00
65TH 0154	1.10	48.70	0.00	0.00	41.40	0.90	0.00	9.00	0.00
65TH 0171	3.70	51.50	0.00	2.50	46.00	0.00	0.00	0.00	0.00
65TH 0174	12.50	56.80	0.50	0.00	39.40	2.00	0.20	1.20	0.00
65TH 0180	7.40	58.70	0.40	0.00	39.90	1.10	0.00	0.00	0.00
65TH 0186	26.00	16.20	0.90	0.00	79.80	2.50	0.30	0.00	0.20
65TH 0191	24.40	16.70	0.20	0.00	77.30	2.30	0.20	0.00	3.40
65TH 0200	4.90	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
65TH 0214	6.50	0.60	0.00	0.00	98.50	0.00	0.90	0.00	0.00
65TH 0216	19.30	14.30	0.30	0.00	83.90	1.60	0.00	0.00	0.00
65TH 0218	14.50	13.20	0.00	0.00	86.70	0.00	0.00	0.10	0.00
65TH 0222	6.10	37.00	0.00	0.00	60.10	3.00	0.00	0.00	0.00
65TH 0232	1.00	71.90	0.00	0.00	27.20	0.00	1.00	0.00	0.00
65TH 0234	0.70	19.20	0.00	0.00	78.10	0.00	2.70	0.00	0.00
65TH 0236	2.30	44.00	0.00	0.00	56.00	0.00	0.00	0.00	0.00
65TH 0244	3.80	67.10	2.40	1.80	28.60	0.00	0.00	0.00	0.00
65TH 0250	0.60	73.70	10.50	0.00	15.80	0.00	0.00	0.00	0.00
65TH 0252	3.30	58.30	5.40	0.60	21.20	0.00	0.00	10.60	3.90
65TH 0254	4.30	54.10	1.20	0.00	28.90	0.00	0.00	15.90	0.00
65TH 0258	13.60	34.10	0.00	0.00	50.90	0.00	0.00	13.20	1.90
65TH 0260	4.80	45.90	0.00	1.90	29.20	0.00	0.00	22.70	0.20
65TH 0264	20.50	31.30	0.00	0.00	46.10	0.00	0.00	21.10	1.40
65TH 0272	2.80	6.10	0.00	0.00	62.50	0.00	0.00	26.40	5.10
65TH 0284	2.60	28.10	0.00	0.00	52.30	0.00	0.00	12.50	7.10
65TH 0288	22.10	56.40	0.60	1.70	25.10	0.00	0.00	16.20	0.10
65TH 0290	2.70	30.90	1.90	3.40	51.40	0.00	0.00	6.80	5.70
65TH 0296	6.00	62.20	8.40	0.00	20.10	0.00	0.00	9.10	0.20
65TH 0300	3.00	44.90	30.20	0.00	20.60	0.00	0.00	4.30	0.00
65TH 0320	5.80	35.70	0.00	0.00	57.30	1.50	0.00	0.50	5.00
65TH 0328	3.70	19.10	0.00	0.00	69.50	9.30	0.00	2.20	0.00
65TH 0330	5.70	54.30	0.00	0.20	37.80	4.70	0.00	0.00	3.00
65TH 0338	8.10	47.30	0.10	0.00	49.60	1.50	1.00	0.00	0.50
65TH 0340	2.10	63.20	3.40	1.40	27.80	0.00	0.00	2.90	1.40
65TH 0342	5.80	81.50	0.00	0.90	14.50	0.00	0.50	0.00	2.60
65TH 0344	8.90	46.10	0.00	0.10	42.00	0.10	2.50	3.80	5.40

Sample No.	Total Sample Weight	Grey Carbonate	Pink Carbonate	Other Paleozoic	Total Crystalline	Dubaunt	Quartz	Greywacke/Argillite	Other Proterozoic
65TH 0346	0.90	51.10	0.00	0.00	45.60	0.00	0.00	0.00	3.30
65TH 0348	1.20	46.30	0.00	0.00	53.70	0.00	0.00	0.00	0.00
65TH 0352	4.20	59.30	0.50	0.00	37.10	3.10	0.00	0.00	0.00
65TH 0354	3.30	76.20	0.00	0.00	22.60	0.00	0.00	1.20	0.00
65TH 0368	1.40	49.30	0.00	10.00	20.00	0.00	0.00	20.70	0.00
65TH 0371	14.30	87.20	0.20	0.00	12.60	0.00	0.00	0.00	0.00
65TH 0378	34.80	68.30	0.00	0.10	31.20	0.00	0.10	0.00	0.30
65TH 0380	11.10	75.50	0.00	0.00	23.90	0.00	0.50	0.00	0.00
65TH 0382	16.60	73.30	0.00	0.20	24.50	0.00	0.30	0.00	1.70
65TH 0386	9.50	62.50	0.20	2.40	32.90	0.00	0.40	0.00	1.50
65TH 0398	5.60	87.50	0.00	0.00	7.50	0.00	0.00	0.00	5.00
65TH 0403	11.60	66.60	1.50	0.10	27.10	0.20	0.30	3.90	0.40
65TH 0405	4.20	74.10	0.00	0.00	24.10	0.00	0.00	1.90	0.00
65TH 0406	0.50	81.60	0.00	0.00	16.30	0.00	0.00	2.60	0.00
65TH 0407	1.00	82.80	0.00	0.00	17.20	0.00	0.00	0.00	0.00
65TH 0408	0.30	93.80	0.00	0.00	6.30	0.00	0.00	0.00	0.00
65TH 0409	6.50	37.20	2.20	0.00	41.00	0.10	0.30	13.30	6.00
65TH 0411	3.30	78.70	0.60	0.00	17.70	0.00	0.00	2.40	0.60
65TH 0422	7.10	84.80	0.70	0.00	13.50	0.00	0.00	1.00	0.00
65TH 0424	13.80	80.70	3.80	0.00	14.20	0.00	0.10	0.70	0.40
65TH 0434	7.20	75.50	1.80	0.60	15.80	0.00	0.10	5.30	1.00
65TH 0440	5.00	67.80	14.00	0.00	17.10	0.00	0.40	0.80	0.00
65TH 0444	1.90	58.10	0.00	0.00	20.40	0.00	0.00	21.50	0.00
65TH 0449	1.80	53.90	1.70	0.00	42.80	0.00	0.00	0.00	1.70
65TH 0452	3.30	61.80	19.30	0.00	12.00	0.00	0.00	4.50	2.40
65TH 0453	5.50	52.90	30.10	0.00	14.60	0.00	0.00	0.70	1.70
65TH 0454	5.50	58.50	19.00	0.00	17.30	0.00	0.00	4.90	0.40
65TH 0455	1.70	77.10	0.00	0.00	22.90	0.00	0.00	0.00	0.00
65TH 0461	10.40	52.20	7.20	0.00	23.00	0.00	0.00	16.80	0.90
65TH 0462	6.00	45.80	0.00	0.00	33.60	0.00	0.00	20.60	0.00
65TH 0463	11.70	35.50	0.60	0.00	37.30	0.00	0.00	23.00	3.70
65TH 0464	6.20	47.40	6.40	0.00	32.20	0.00	0.00	14.00	0.00
65TH 0466	0.30	51.50	0.00	3.00	36.40	0.60	0.00	9.10	0.00
65TH 0468	1.00	56.30	20.80	0.00	11.50	0.00	0.00	11.50	0.00
65TH 0476	29.10	11.00	0.00	2.60	26.70	0.00	0.00	59.40	0.30
65TH 0477	49.80	49.00	5.80	0.00	27.90	0.00	0.10	15.50	1.70
65TH 0481	1.70	11.70	0.00	0.00	71.30	4.70	0.00	1.70	10.50
65TH 0482	1.40	32.40	2.10	0.00	63.50	0.00	0.00	2.10	0.00
65TH 0486	10.10	41.90	0.00	1.70	36.30	0.00	0.00	15.00	5.00
65TH 0490	4.60	31.20	1.50	0.00	33.00	5.90	0.00	28.30	0.00
65TH 0492	20.50	33.60	0.50	0.00	29.90	4.40	0.00	27.40	4.10
65TH 0494	13.00	55.10	1.60	0.30	20.50	0.40	0.30	21.80	0.10
65TH 0496	9.60	41.00	2.60	0.00	44.80	3.20	0.00	8.30	0.00
65TH 0498	17.90	38.50	1.60	0.00	40.10	0.80	0.50	12.50	6.10
65TH 0501	18.00	60.40	2.80	0.10	29.20	1.40	0.00	5.20	0.80
65TH 0502	39.60	68.30	1.90	0.00	22.00	0.80	0.10	3.00	3.80
65TH 0503	47.40	66.40	3.80	0.00	24.20	0.80	0.20	2.60	2.10
65TH 0504	50.20	56.30	13.50	0.00	24.40	0.80	0.10	3.10	1.80
65TH 0505	37.40	47.70	3.00	0.00	43.10	0.90	0.50	3.80	1.10
65TH 0506	20.40	51.50	0.80	0.00	41.50	0.70	0.50	4.70	0.20
65TH 0508	42.60	42.00	11.50	0.00	42.40	1.50	0.10	2.00	0.40
65TH 0510	7.60	34.30	1.30	0.00	42.60	14.60	0.00	4.50	2.60
65TH 0511	4.80	36.40	2.30	0.00	47.30	2.70	1.50	3.10	6.70
65TH 0512	21.90	62.90	0.20	0.00	36.70	0.00	0.00	0.20	0.00
65TH 0513	52.20	64.60	0.10	0.00	33.70	0.30	0.10	1.20	0.10
65TH 0514	31.70	61.00	0.20	0.00	35.50	0.80	0.20	0.90	1.30
65TH 0515	24.38	70.80	0.20	0.00	25.50	0.50	0.10	1.00	1.90
65TH 0517	7.00	66.20	0.30	0.00	31.10	0.00	0.00	0.90	1.50
65TH 0520	17.60	26.10	0.10	0.00	72.80	0.30	0.00	0.00	0.70
65TH 0523	2.30	97.80	0.00	0.00	2.20	0.00	0.00	0.00	0.00

Sample No.	Total Sample Weight	Grey Carbonate	Pink Carbonate	Other Paleozoic	Total Crystalline	Dubaunt	Quartz	Greywacke/ Argillite	Other Proterozoic
65TH 0532	14.30	91.80	0.00	0.00	7.70	0.00	0.00	0.00	0.50
65TH 0566	24.60	5.80	0.00	0.00	93.50	0.00	0.00	0.20	0.50
71MLA0001	15.90	94.00	0.30	0.00	5.60	0.00	0.00	0.00	0.00
71MLA0002	6.50	99.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00
71MLA0003	3.90	98.70	0.00	0.00	1.30	0.00	0.00	0.00	0.00
71MLA0004	6.00	98.50	0.00	0.00	1.50	0.00	0.00	0.00	0.00
71MLB0001	4.20	75.10	0.20	0.00	24.70	0.00	0.00	0.00	0.00
71MLB0002	3.10	84.00	0.00	0.00	16.00	0.00	0.00	0.00	0.00
71MLC0001	0.80	15.60	0.00	0.00	76.70	7.80	0.00	0.00	0.00
71MLC0002	2.00	43.50	0.00	0.00	55.50	1.00	0.00	0.00	0.00
71MLC0004	17.60	72.40	0.00	0.00	23.10	4.60	0.00	0.00	0.00
71MLC0005	2.30	35.60	1.30	0.00	42.20	1.80	0.00	19.10	0.00
71MLD0003	24.80	78.00	0.00	0.00	21.40	0.70	0.00	0.00	0.00
71MLD0004	12.20	69.30	0.00	0.00	29.20	1.60	0.00	0.00	0.00
71MLF0009	20.30	58.50	0.00	0.00	38.70	1.60	0.00	0.40	0.70
71MLG0001	5.90	37.00	0.00	6.30	52.50	1.70	0.00	1.20	1.40
71MLG0002	1.10	38.40	0.00	0.00	59.80	1.80	0.00	0.00	0.00
71MLH0002	2.30	37.00	0.00	0.00	35.60	3.10	0.00	24.20	0.00
71MLH0006	3.90	25.90	0.00	0.00	69.00	1.50	0.00	3.10	0.50
71MLH0009	5.40	72.80	1.10	0.00	25.00	0.00	0.00	1.10	0.00
71MLI0002	13.78	66.70	0.00	0.00	26.10	0.00	0.00	4.60	2.50
71MLI0003	1.80	77.80	8.90	0.00	13.30	0.00	0.00	0.00	0.00
71MLI0003A	19.80	65.20	13.40	0.20	17.50	0.00	0.00	3.10	0.70
71MLI0004	4.20	60.20	13.00	0.00	15.60	0.90	0.00	9.10	1.20
71MLI0006	18.40	44.10	1.70	0.00	22.70	0.40	0.20	27.70	3.30
71MLJ0002	3.30	44.30	4.90	0.00	21.70	0.00	0.00	29.10	0.00
71MLK0004	0.40	4.70	0.00	0.00	27.90	0.00	0.00	62.80	4.60
71MLK0005	1.80	1.10	0.00	0.00	24.60	0.00	0.00	68.20	6.10
71MLL0004	1.90	3.80	0.00	0.00	33.90	0.00	0.00	59.10	3.20
71MLL0005	3.50	11.60	4.00	0.00	20.50	0.00	0.00	61.60	2.30
71MLL0009	1.30	39.10	3.10	0.00	55.50	0.00	0.00	2.30	0.00
71MLM0001	4.40	41.30	42.90	0.00	10.90	0.00	0.00	4.10	0.90
71MLM0004	14.40	42.60	42.10	0.00	8.20	0.00	0.00	6.70	0.40
71MLN0002	3.40	37.20	1.50	0.00	31.60	0.00	0.00	29.80	0.00
71MLN0004	2.70	4.50	0.00	17.10	58.40	0.00	0.00	19.30	0.70
71MLN0005	2.50	1.60	0.00	0.00	71.90	0.00	0.00	19.00	7.50
86HU 0002	7.80	57.40	0.00	0.00	38.50	0.30	0.00	2.30	1.60
86HU 0004	0.50	35.30	3.90	0.00	58.80	2.00	0.00	0.00	0.00

APPENDIX F
HEAVY MINERAL ANALYSES, HUDSON BAY

A. Description of Major Heavy Minerals

Nonopaque Minerals

Garnet: (s.g. 4.1-4.3) Garnet is present at all sample sites ranging in abundance from 3-25%. It occurs as angular grains with conchoidal fracture and, less commonly, as rounded and frosted grains or, rarely, in euhedral crystals. Colourless to pink and pinkish orange almandine garnets are the most prevalent although isolated grains of green (gahnite) and purple (pyrope) varieties are present. Garnet grains may contain inclusions giving the mineral a dusty appearance.

Epidote: (s.g. 3.4-3.5) Epidote is distributed throughout the bay, ranging in abundance from 3-36%. It occurs as very pale yellow to yellow green equidimensional angular to subrounded grains with a vitreous lustre. Rounded grains are less common; euhedral crystals rare. Some grains are milky with sucrosic texture.

Orthopyroxene: (s.g. 3.4-3.7) The orthopyroxene consists predominantly of hypersthene (<1-27%) which occurs as elongate, prismatic to stubby grains with irregular fracture generally along the cleavage or as irregular grains with conchoidal fracture. Grains are rarely rounded. The mineral is colourless to light and dark brown to yellow and generally has a vitreous lustre. Bronzite, a variety of orthopyroxene containing schiller structure, is included within this mineral group.

Clinopyroxene: The group is essentially composed of two varieties:

(1) Diopside (s.g. 3.2-3.6) ranges in abundance from <1-34% and occurs predominantly as clear, angular to subrounded, elongate to equidimensional, grains with vitreous lustre which vary in colour from very pale green to bluish green to emerald green.

(2) Augite (s.g. 2.96-3.52) occurs in red brown, elongate, irregular grains commonly with a dentate edge. Only locally abundant in Hudson Bay.

Amphibole: (s.g. 3.0 -3.5) Amphiboles consist predominantly of green to dark green hornblende (<1-29%) with red-brown to brown basaltic hornblende present to a lesser extent (0-16%). The grains are elongate to equidimensional and generally angular to subrounded with occasional rounded grains.

Siderite: (s.g. 3.50-3.96) The abundance and distribution of siderite varies considerably ranging up to 55% of the heavy mineral suite. The mineral is commonly yellow brown to tan and occurs as single elongate crystals, crystalline aggregates (framboids) or irregular globular masses; rarely euhedral. Grains may be clear or "dirty" with a vitreous to earthy lustre. Less commonly, siderite appears as grey, angular grains exhibiting sucrosic texture.

Titanite: (s.g. 3.45-3.55) Titanite is ubiquitous throughout the bay ranging in abundance from <1-13%. The mineral occurs as irregular, subangular grains with conchoidal fracture or, less commonly, diamond shaped euhedral grains. Titanite is commonly pale yellow to light brown with a vitreous lustre and may be partially altered to leucoxene.

Other less abundant nonopaque minerals in the heavy mineral suite include kyanite, monazite, rutile, spinel, staurolite, zircon and occasionally anatase and barite.

Opaque Minerals

Hematite: (s.g. 5.2) Hematite occurs at all sites but ranges in abundance from 1-53%. Grain colour and morphology varies and includes steel grey angular to well rounded, brick red irregular, and angular to botryoidal varieties with an earthy lustre. Specular hematite grains are also present and euhedral grains are rare.

Ilmenite: (s.g. 4.4-4.8) Ilmenite is abundant (1-18%) within

the heavy mineral suite and occurs as black, angular to rounded to platy grains with a metallic to vitreous lustre. Irregular grains have a conchoidal fracture. Ilmenite alters to leucoxene.

Pyrite: (s.g. 4.95-5.0) Although not common, pyrite can be locally abundant (19%). It occurs in irregular grains exhibiting conchoidal fracture, euhedral (cubic) crystals or as botryoidal or framboidal masses. Pyrite may be coated with goethite, an alteration product. Occasionally, pyritized forams are present.

Less abundant opaque minerals include goethite and leucoxene, alteration products of the iron and titanium minerals respectively.

B. Results of Heavy Mineral Analyses, Hudson Bay

Size fraction: 0.063 - 0.250mm
 Heavy Liquid: Methylene Iodide (s.g. 3.31)
 Sample Number: 129

TABLE 1

Sample No.	HMML = Weight Light Fraction (grams)				HMHM = Weight Heavy Fraction (grams)							
	HMLM	HMHM	HMMW	Hbl	BHbl	Epi	Gar	Goe	Hem	Ilm	Kyn	Leu
65HU 0073	98.8	1.0	0.2	1.9	0.4	24.9	2.8	0.4	23.0	6.9	0.4	5.2
65HU 0084	98.7	0.9	0.1	0.7	0.2	10.7	3.1	6.0	53.7	8.9	0.0	2.9
65HU 0101	98.9	1.0	0.1	5.8	1.1	18.0	13.8	2.7	9.3	5.6	0.2	2.2
65HU 0122	98.8	1.1	0.1	7.5	1.8	20.6	14.9	0.7	8.4	7.7	1.4	2.9
65HU 0126	99.4	0.5	0.1	6.5	0.0	19.6	19.6	1.1	8.0	5.1	0.0	3.1
65HU 0128	98.2	0.5	0.2	7.6	1.7	15.2	12.8	0.0	6.8	10.4	0.5	0.9
65HU 0146	98.8	0.8	0.3	9.3	2.7	16.7	11.6	0.0	7.6	13.1	0.4	1.8
65HU 0149	98.6	0.9	0.5	7.3	2.0	21.3	12.7	0.4	13.3	4.4	0.4	0.9
65HU 0155	98.2	1.0	0.5	6.4	1.5	14.0	12.0	0.7	8.7	0.7	0.6	1.6
65HU 0159	98.4	1.2	0.4	4.0	1.6	20.4	11.3	0.9	10.2	5.0	0.2	1.4
65HU 0163	98.3	1.2	0.5	10.7	3.1	18.0	15.1	1.1	7.8	12.2	0.2	0.9
65HU 0268	98.6	0.9	0.4	4.0	0.4	14.2	18.0	1.3	6.9	8.0	0.4	2.9
65HU 0300	98.3	0.9	0.6	2.2	1.6	12.7	17.4	0.9	6.9	6.7	0.0	2.4
65HU 0309	97.9	1.2	0.6	5.4	0.7	16.1	15.8	0.9	8.1	7.7	0.0	1.8
65HU 07.0	98.9	0.8	0.3	9.0	0.0	18.6	16.8	1.8	6.8	1.2	0.0	1.4
65HU 11.1	98.2	0.9	0.7	2.0	1.3	16.0	19.3	0.7	10.2	7.8	0.7	1.6
65HU J313	99.5	0.4	0.1	3.8	2.2	15.3	12.0	0.9	5.3	6.4	1.1	2.2
65HU 0314	99.2	0.6	0.2	9.0	0.0	19.7	13.3	1.0	8.7	1.3	0.2	1.3
65HU 0316	99.4	0.5	0.1	5.6	2.4	14.9	17.6	2.4	5.6	7.3	0.7	1.8
65HU 0325	99.1	0.9	0.5	3.8	1.1	12.7	15.5	1.1	11.6	9.7	0.7	2.7
65HU 0508	99.2	0.6	0.2	8.4	2.7	25.1	10.0	0.9	6.4	10.4	0.4	1.8
65TH 0041	98.6	0.5	0.1	12.3	0.0	17.7	18.3	1.0	6.7	2.7	0.0	0.3
65TH 0044	98.4	0.8	0.5	9.3	4.9	12.0	15.5	0.4	7.8	8.0	0.9	1.1
65TH 0073	99.7	0.3	0.0	5.1	2.7	23.3	15.3	0.7	8.4	6.9	0.4	1.1
65TH 0082	99.2	0.6	0.2	12.7	4.4	24.9	8.4	0.0	8.0	8.2	0.0	0.9
65TH 0092	98.7	0.9	0.4	9.8	1.1	25.6	14.2	0.2	15.0	7.1	0.2	0.7
65TH 0095	98.9	0.9	0.2	9.3	1.1	18.4	21.3	0.0	6.7	7.6	2.2	0.7
65TH 0103	99.4	0.5	0.1	9.3	0.9	31.0	9.1	0.9	10.4	6.4	0.0	1.3
65TH 0107	99.8	0.2	0.0	7.1	0.9	30.0	7.8	0.0	10.0	7.6	0.4	0.7
65TH 0111	99.7	0.3	0.1	9.1	0.9	28.5	6.7	0.2	7.8	10.9	0.2	1.3
65TH 0120	97.9	0.9	1.2	6.9	2.2	7.6	14.7	0.0	7.1	12.7	0.0	0.7
65TH 0130	99.0	0.7	0.3	7.3	2.0	24.0	10.0	0.0	8.0	11.1	0.0	1.5
65TH 0132	98.5	1.0	0.4	12.0	2.4	15.3	13.5	0.4	8.9	13.6	0.4	1.3
65TH 0137	98.7	1.0	0.3	16.7	6.0	18.0	12.2	0.4	1.1	4.9	0.9	0.0
65TH 0138	98.7	0.9	0.4	10.9	2.2	23.3	8.2	0.2	9.3	9.3	0.0	1.1
65TH 0146	98.8	0.9	0.1	12.4	1.8	18.9	11.8	0.2	11.6	5.1	0.4	1.1
65TH 0148	98.9	0.5	0.1	8.9	1.5	19.3	6.2	1.3	3.6	6.7	0.7	3.6
65TH 0157	98.9	0.7	0.2	5.8	0.9	17.1	13.3	2.0	5.6	15.6	0.7	1.1
65TH 0161	99.6	0.4	0.0	7.3	0.2	15.1	14.2	2.7	6.9	9.3	0.7	4.9
65TH 0174	98.8	0.9	0.3	11.8	2.9	27.3	13.8	0.2	8.7	11.1	0.4	0.4
65TH 0180	98.4	1.0	0.6	7.1	2.2	8.9	19.3	2.4	6.0	10.2	0.0	0.9
65TH 0185	99.0	0.6	0.4	8.2	1.6	15.6	14.3	0.7	4.4	11.1	1.1	0.4
65TH 0186	97.4	2.3	0.3	25.1	3.8	14.7	16.4	0.4	1.5	2.9	1.1	0.2
65TH 0191	98.9	0.9	0.2	8.4	1.3	22.9	17.1	0.2	7.8	8.4	2.0	0.4
65TH 0204	98.6	1.2	0.2	22.2	15.5	5.5	13.3	0.2	0.9	4.0	0.0	0.7
65TH 0207	99.0	0.5	0.5	17.5	3.8	6.9	14.4	0.4	5.6	10.9	0.4	1.7
65TH 0213	99.1	0.4	0.5	13.4	4.2	7.3	13.6	0.2	4.2	11.9	0.2	0.4

Sample No.	HMLM	HMHM	HMMU	Hbl	BHbl	Epi	Gar	Goe	Hem	Ilm	Kyn	Leu
65TH 0218	98.8	0.7	0.5	14.4	5.1	9.6	14.0	0.2	0.9	7.3	0.7	0.2
65TH 0222	98.8	0.9	0.3	19.3	4.1	13.6	18.1	1.6	2.0	5.2	0.9	0.5
65TH 0224	99.0	0.8	0.2	8.7	1.3	21.1	16.0	0.7	9.1	8.0	0.2	0.7
65TH 0232	99.3	0.6	0.1	6.7	0.9	20.7	12.7	0.7	7.1	6.7	1.1	2.2
65TH 0234	99.0	0.9	0.1	29.4	3.3	17.1	7.6	1.3	3.3	3.3	0.2	3.1
65TH 0236	99.4	0.5	0.1	12.4	3.3	22.9	11.1	1.1	4.0	4.7	1.1	2.9
65TH 0246	99.0	1.0	0.0	3.8	0.9	13.0	17.0	4.9	13.4	8.0	0.4	0.9
65TH 0247	99.1	0.6	0.1	0.0	0.0	24.4	16.8	0.3	10.9	1.0	1.1	3.6
65TH 0257	98.5	0.8	0.5	2.7	0.4	29.8	12.4	0.0	2.7	5.1	0.2	1.3
65TH 0259	98.5	1.0	0.5	9.0	2.8	22.0	16.4	0.2	3.5	2.3	0.9	1.6
65TH 0284	97.5	1.8	0.7	7.0	1.8	21.3	14.3	0.0	2.5	2.2	0.2	1.1
65TH 0287	98.5	0.7	0.5	0.9	0.2	21.2	17.0	0.2	4.9	8.9	0.7	1.6
65TH 0288	98.2	1.0	0.7	6.2	2.2	24.2	10.2	0.9	3.1	3.6	0.2	0.7
65TH 0328	99.7	0.3	0.0	5.8	1.8	28.7	8.9	1.1	3.6	4.7	0.0	1.1
65TH 0332	99.4	0.4	0.1	14.2	0.9	20.4	9.8	0.4	5.8	6.4	0.0	3.3
65TH 0338	99.5	0.3	0.2	5.0	0.2	15.3	11.7	0.0	10.7	12.3	1.7	3.0
65TH 0344	99.0	0.7	0.3	5.7	1.6	17.1	14.2	0.7	8.7	10.2	0.9	3.6
65TH 0348	99.5	0.4	0.1	6.2	0.7	21.3	10.7	0.4	6.9	6.8	0.7	2.7
65TH 0352	99.2	0.6	0.2	11.8	0.7	23.0	10.7	1.1	8.7	4.7	0.7	1.3
65TH 0377	99.3	0.4	0.3	6.2	0.9	11.6	24.2	0.4	3.8	8.2	0.7	1.8
65TH 0380	99.0	0.5	0.5	15.1	3.8	12.4	17.1	0.0	2.7	4.0	0.4	0.7
65TH 0382	99.2	0.4	0.4	7.3	3.0	9.4	21.0	1.4	4.6	9.8	0.7	1.4
65TH 0386	98.8	0.5	0.2	4.4	0.9	14.2	25.3	0.4	3.1	6.0	0.9	1.1
65TH 0408	98.7	1.1	0.0	7.5	3.4	16.7	18.3	0.9	1.6	6.8	0.2	0.7
65TH 0422	99.6	0.3	0.1	9.8	2.9	20.9	14.4	0.2	4.7	8.2	0.2	1.6
65TH 0439	98.5	1.1	0.4	9.3	4.0	18.7	10.0	1.1	2.2	4.9	0.7	1.3
65TH 0443	99.2	0.7	0.2	9.1	4.4	19.8	10.9	3.3	5.8	6.9	0.7	2.0
65TH 0449	98.1	0.6	0.1	8.9	3.6	20.2	16.7	0.9	6.7	7.3	2.2	2.0
65TH 0453	99.3	0.6	0.1	4.3	1.6	16.1	15.8	0.7	10.0	6.3	1.6	2.3
65TH 0455	99.0	0.8	0.2	5.8	0.9	13.5	19.3	1.6	8.0	4.2	1.1	2.9
65TH 0456	98.6	0.9	0.2	10.2	0.0	11.6	22.0	7.1	8.2	3.6	0.7	2.0
65TH 0459	99.3	0.7	0.0	1.4	3.2	17.3	17.0	0.9	8.1	13.6	0.0	1.6
65TH 0461	98.8	1.1	0.1	1.3	0.7	16.0	13.3	0.4	4.4	10.0	0.9	2.4
65TH 0463	98.6	0.9	0.3	1.4	0.9	19.6	11.9	0.0	1.4	8.4	0.7	0.0
65TH 0464	98.7	0.8	0.2	2.7	0.9	14.7	13.6	3.1	8.7	5.8	0.2	1.3
65TH 0466	98.4	0.4	0.4	4.0	1.3	16.0	10.2	0.4	7.8	10.2	0.2	4.0
65TH 0468	99.3	0.6	0.1	6.0	2.7	17.1	12.7	1.8	7.8	6.0	2.2	2.7
65TH 0475	98.6	1.0	0.2	3.3	2.7	15.6	14.9	1.6	6.4	6.9	0.9	2.4
65TH 0476	98.5	1.0	0.1	7.2	0.7	15.8	11.5	0.9	4.5	6.6	0.7	2.0
65TH 0477	98.5	1.1	0.4	3.0	1.6	12.0	15.9	1.6	6.9	6.2	0.5	1.8
65TH 0480	98.7	0.8	0.4	0.4	1.8	18.7	18.6	1.1	8.4	6.7	0.5	1.4
65TH 0482	99.4	0.4	0.2	4.7	0.2	11.8	14.9	1.1	8.0	8.9	1.3	2.2
65TH 0484	98.7	0.7	0.6	12.7	2.9	19.6	11.6	1.1	8.2	2.9	1.1	2.7
65TH 0486	98.9	0.7	0.3	3.8	1.6	12.6	10.4	0.2	10.4	5.9	0.5	2.5
65TH 0502	96.3	0.8	2.9	17.7	2.8	17.5	11.8	0.7	7.8	7.1	0.2	2.4
65TH 0514	94.6	2.4	3.0	10.6	4.1	12.7	12.7	0.2	17.1	18.3	0.0	1.8
65TH 0532	99.8	0.1	0.0	5.3	1.1	14.9	20.7	0.0	6.0	10.2	0.7	0.4
65TH 0544	99.5	0.3	0.1	7.6	2.2	18.2	13.8	0.4	6.9	8.7	0.2	1.6
65TH 0555	99.3	0.5	0.1	13.7	3.8	22.2	12.2	0.4	4.4	8.0	0.0	0.6
71MLA0002	-	-	-	12.5	0.0	14.4	18.0	0.6	1.5	0.5	0.0	1.2
71MLA0003	-	-	-	16.5	0.0	12.5	15.8	2.3	1.5	0.5	0.0	1.3
71MLA0004	-	-	-	6.8	0.0	11.0	16.8	1.4	1.4	1.7	0.0	0.3
71MLB0002	-	-	-	13.7	0.0	16.5	22.8	0.5	1.8	1.5	0.3	0.5
71MLB0003	-	-	-	11.0	3.0	18.0	22.3	0.3	3.0	1.0	0.0	0.8
71MLC0001	-	-	-	13.6	1.8	27.6	14.7	0.0	4.6	2.5	1.0	0.0
71MLC0004	-	-	-	7.0	0.8	27.3	22.5	0.0	10.5	5.3	0.3	0.5
71MLD0002	98.4	1.2	0.2	11.3	0.0	23.5	20.0	0.0	11.0	2.0	1.0	0.3
71MLD0003	-	-	-	6.3	0.0	23.0	21.3	0.0	7.5	3.0	0.0	0.5
71MLD0004	98.4	0.7	0.2	5.8	0.0	31.7	7.3	0.0	17.5	2.5	0.5	0.3
71MLD0006	-	-	-	4.5	0.0	36.7	10.3	0.0	9.5	1.8	0.0	0.8
71MLF0009	-	-	-	4.5	0.0	11.8	6.5	0.7	3.3	1.3	0.0	1.5
71MLG0001	98.6	0.3	0.2	6.5	0.0	20.0	14.3	0.5	12.8	2.5	1.6	2.5

Sample No.	HMLM	HMHM	HMMW	Hbl	BHbl	Epi	Gar	Goe	Hem	Ilm	Kyn	Leu
71MLN0002	-	-	-	2.8	0.0	18.7	15.0	0.0	5.5	2.0	1.0	2.3
71MLN0004	98.4	0.8	0.3	7.5	0.0	25.5	13.8	2.5	11.5	2.8	1.0	1.0
71MLN0006	-	-	-	14.0	0.0	23.0	13.0	1.3	10.0	5.3	0.0	1.5
71MLN0008	-	-	-	13.5	0.0	22.8	15.3	1.0	4.3	3.3	0.3	2.8
71MLN0009	98.2	1.3	0.5	21.0	0.0	12.3	19.0	0.3	10.8	5.0	0.0	0.8
71MLI0002	99.0	0.7	0.5	7.8	0.0	24.5	12.6	0.8	10.5	5.4	0.8	1.0
71MLI0003	-	-	-	6.3	0.0	30.5	12.8	0.3	5.5	3.5	0.3	1.8
71MLI0004	-	-	-	11.5	0.0	27.5	14.5	0.8	6.3	2.3	1.0	1.3
71MLI0006	98.4	1.3	0.8	5.0	0.0	15.9	24.4	0.4	11.5	1.3	1.0	3.8
71MLJ0001	-	-	-	4.3	0.0	21.8	17.5	1.3	7.0	2.5	0.3	3.0
71MLK0004	-	-	-	3.8	0.0	16.8	16.5	5.3	7.3	1.8	0.8	2.5
71MLK0005	-	-	-	1.5	0.0	13.3	8.5	0.3	16.0	0.8	0.5	1.5
71MLL0001	-	-	-	1.3	0.0	15.0	7.0	0.0	15.0	2.5	0.0	1.5
71MLL0005	-	-	-	5.5	0.0	21.5	13.8	1.0	8.8	3.0	0.3	1.0
71MLL0009	-	-	-	8.0	0.0	19.5	16.3	3.0	6.0	2.5	0.0	0.5
71MLM0001	97.3	1.4	0.6	6.5	0.0	7.5	10.0	4.3	45.3	0.0	1.0	1.0
71MLM0004	98.7	0.8	0.4	7.3	0.0	20.5	14.3	2.3	8.0	3.5	0.5	2.3
71MLN0002	-	-	-	6.0	0.0	25.3	9.5	0.8	3.8	3.3	0.0	0.5
71MLN0004	-	-	-	2.0	0.0	14.8	10.3	0.3	2.0	1.5	0.0	0.0
71MLN0005	-	-	-	1.3	0.0	12.5	13.8	0.0	1.3	0.5	0.0	0.0

TABLE 2

Sample No.	Legend										Zir	Other
	Mon	Pyr	Dio	Aug	Hyp	Rut	Sid	Spi	Sta	Tit		
65HU 0073	0.0	4.3	2.9	0.1	3.9	0.4	5.9	0.0	0.4	2.0	1.6	12.5
65HU 0084	0.0	0.2	1.0	0.2	1.1	0.4	3.6	0.0	0.0	2.2	0.4	4.6
65HU 0101	0.0	0.2	14.7	1.1	10.7	0.2	0.4	0.9	0.4	5.1	1.8	5.9
65HU 0122	0.2	0.0	10.4	0.9	13.6	0.2	1.4	0.0	0.7	4.8	0.7	1.3
65HU 0126	0.2	0.0	16.9	0.9	8.2	0.2	0.4	0.0	0.4	4.5	2.0	3.2
65HU 0128	0.2	0.0	11.7	2.3	14.5	0.5	3.6	0.0	0.0	4.5	3.6	3.3
65HU 0146	1.1	0.2	7.6	0.0	6.9	0.2	11.1	0.2	1.1	2.2	1.3	4.8
65HU 0149	0.0	0.0	11.1	0.2	7.3	0.2	9.3	0.9	1.3	2.4	0.7	3.8
65HU 0155	0.0	0.0	8.2	0.2	7.1	0.0	30.9	0.0	0.9	1.8	1.6	3.1
65HU 0159	0.4	0.2	8.8	1.4	10.8	0.2	15.8	0.7	1.1	1.8	1.8	1.9
65HU 0163	0.2	0.0	8.9	0.9	6.9	0.7	5.1	0.0	1.3	2.7	1.6	2.6
65HU 0268	0.9	0.0	11.3	2.2	15.1	0.9	1.3	0.0	0.0	4.9	2.9	4.3
65HU 0300	0.0	0.0	13.1	1.6	23.5	0.0	1.1	0.0	0.4	3.8	2.2	2.9
65HU 0309	0.0	0.0	16.1	0.9	13.6	0.9	1.1	0.0	0.2	3.6	2.0	5.0
65HU 0310	0.0	0.2	15.4	0.0	17.4	0.4	2.2	0.0	0.2	3.6	0.8	3.7
65HU 0311	0.0	0.2	6.2	3.6	15.3	0.4	3.6	0.0	1.1	4.9	1.6	3.4
65HU 0313	0.0	0.0	13.1	0.0	16.9	0.4	8.2	0.0	0.4	6.9	1.1	3.7
65HU 0314	0.2	0.3	15.5	0.3	12.7	2.7	4.3	0.0	0.0	3.5	2.7	3.4
65HU 0316	0.4	0.0	8.4	1.8	18.9	1.3	2.2	0.0	0.4	2.9	1.8	3.5
65HU 0325	0.0	0.0	8.9	0.9	15.5	0.2	3.3	0.0	0.4	5.6	2.4	4.0
65HU 0508	0.0	0.0	10.4	0.7	6.9	0.2	4.0	0.7	0.7	6.0	0.9	3.3
65TH 0041	0.7	0.0	11.3	0.0	10.3	3.0	1.3	0.0	0.0	4.0	6.7	3.7
65TH 0044	0.0	1.6	8.9	0.9	10.4	1.8	4.7	0.0	1.1	4.0	2.7	4.0
65TH 0073	0.2	0.0	10.4	0.4	11.1	0.4	0.4	0.0	0.2	6.7	1.6	4.6
65TH 0082	0.7	0.0	8.0	1.3	9.3	0.2	0.0	0.0	0.2	6.7	1.6	4.4
65TH 0092	0.2	1.3	6.0	2.0	6.4	0.2	0.0	0.0	0.7	4.7	0.7	4.0
65TH 0095	0.0	0.0	10.0	0.9	5.8	0.2	0.0	0.0	0.7	9.3	3.3	2.4
65TH 0103	0.0	0.2	10.3	0.0	8.5	0.7	0.2	0.0	0.2	6.4	1.1	3.0
65TH 0107	0.9	0.2	10.7	0.0	4.9	0.2	0.0	0.0	0.7	12.7	0.9	4.4
65TH 0111	0.2	0.2	11.7	0.4	8.2	0.2	0.2	0.0	0.9	6.5	1.1	4.7
65TH 0120	0.9	0.0	13.8	1.3	8.7	0.2	0.0	0.0	0.2	14.4	3.3	5.3
65TH 0130	1.1	0.0	11.6	0.4	7.1	0.0	3.1	0.7	1.1	3.6	2.7	4.7
65TH 0132	0.2	0.0	11.8	0.0	6.9	0.2	2.2	0.0	0.7	4.2	1.3	4.6
65TH 0137	0.0	0.4	14.7	0.2	6.4	0.2	0.2	0.0	0.9	13.1	1.6	2.0
65TH 0138	0.0	0.0	15.6	1.8	7.6	0.0	2.0	0.0	0.0	4.0	0.7	3.8
65TH 0146	0.0	0.4	16.2	0.0	7.3	0.0	1.6	0.4	0.9	5.6	0.7	3.5
65TH 0148	0.4	0.7	10.9	0.2	8.7	0.7	15.8	1.1	0.2	6.0	0.2	3.5
65TH 0157	0.0	0.2	11.0	1.1	10.4	0.9	1.6	0.2	1.8	4.7	1.3	4.2
65TH 0161	0.0	0.2	8.4	0.2	12.9	2.7	0.0	0.0	1.8	3.3	4.0	5.1
65TH 0174	0.0	1.3	9.8	0.4	4.2	0.0	0.0	0.0	0.4	4.4	0.4	2.4
65TH 0180	0.0	0.2	15.8	0.0	15.6	0.2	0.4	0.0	0.4	5.0	2.4	3.1
65TH 0185	0.4	0.0	10.9	0.0	13.0	0.4	0.2	0.2	1.1	8.9	3.3	4.1
65TH 0186	0.0	0.2	13.1	0.7	5.6	0.4	0.0	0.0	0.2	8.4	0.9	4.3
65TH 0191	0.4	4.9	5.1	0.2	10.0	0.2	0.0	0.2	0.0	4.7	1.6	4.2
65TH 0204	0.0	0.0	12.4	0.0	17.3	0.7	0.4	0.0	0.4	1.5	0.9	4.0
65TH 0207	0.0	1.1	12.7	0.0	7.8	0.4	1.3	0.0	0.0	7.3	3.6	4.1
65TH 0213	0.0	0.4	14.4	0.2	8.9	0.4	0.2	0.0	0.4	12.2	3.1	4.3
65TH 0218	0.4	0.0	18.9	0.2	10.7	0.2	0.2	0.0	0.2	10.0	2.9	3.9
65TH 0222	0.0	0.7	12.2	0.2	10.2	0.2	0.0	0.0	0.7	5.2	1.4	3.6
65TH 0224	0.0	0.0	9.3	0.0	12.0	0.4	0.7	0.2	0.2	6.4	1.3	3.6
65TH 0232	0.0	0.0	11.8	0.4	13.3	0.0	0.7	0.7	0.4	7.6	2.2	4.2
65TH 0234	0.0	0.0	9.1	3.3	7.7	0.2	0.4	0.0	0.7	3.3	0.7	5.9
65TH 0236	0.0	0.0	13.6	0.2	8.9	0.9	0.4	0.0	2.2	3.6	1.3	5.3

Sample No.	Mon	Pyr	Dio	Aug	Hyp	Rut	Sid	Spi	Sta	Tit	Zir	Other
65TH 0246	0.4	0.0	12.8	2.2	13.2	0.0	1.3	0.0	0.7	2.7	1.3	3.1
65TH 0247	0.3	0.3	17.0	0.6	13.2	0.3	0.3	0.0	0.6	6.4	2.0	2.2
65TH 0257	0.4	0.0	13.3	0.7	18.4	0.4	1.1	0.0	0.9	3.7	1.8	4.6
65TH 0259	0.5	0.0	14.3	4.1	13.6	0.7	0.2	0.0	0.2	2.3	1.8	3.5
65TH 0284	0.2	0.0	20.2	0.7	15.7	0.4	0.0	0.2	0.0	3.4	3.8	4.9
65TH 0287	0.2	0.2	14.3	2.0	19.2	0.2	1.3	0.0	0.0	3.6	0.4	2.9
65TH 0288	0.2	0.0	18.7	1.3	15.8	0.4	0.0	0.2	0.0	5.1	4.0	2.9
65TH 0328	0.4	2.0	16.0	0.4	12.4	0.2	1.3	0.2	0.7	6.9	0.9	2.9
65TH 0332	0.0	0.8	13.8	1.3	11.7	0.0	1.6	0.0	0.4	4.7	1.1	3.3
65TH 0338	0.7	0.2	4.7	0.3	5.7	0.3	14.7	0.0	0.3	3.0	4.0	6.1
65TH 0344	0.0	0.0	8.9	0.9	7.1	0.2	6.0	0.2	0.9	8.0	1.6	3.4
65TH 0348	0.0	0.0	14.0	0.0	8.7	0.9	7.1	0.0	0.7	5.8	2.2	4.2
65TH 0352	0.4	0.0	8.0	1.1	10.9	0.2	1.6	1.3	1.6	8.4	1.1	2.8
65TH 0377	0.2	0.2	8.7	0.0	17.1	0.9	0.0	0.0	1.1	7.6	2.4	3.9
65TH 0380	0.0	0.7	15.6	1.6	14.7	0.4	0.9	0.0	0.2	4.9	2.0	2.9
65TH 0382	0.2	0.4	10.3	1.1	16.0	0.0	1.6	0.0	0.2	5.5	3.0	3.4
65TH 0386	0.2	0.0	14.4	0.2	11.1	1.6	0.9	0.0	0.4	4.7	2.9	7.3
65TH 0408	0.7	0.0	17.8	0.5	15.2	0.7	0.5	0.7	0.5	2.3	1.1	4.0
65TH 0422	0.0	0.0	10.9	0.4	8.9	0.4	1.3	0.2	0.9	9.3	1.8	2.9
65TH 0439	0.2	0.0	16.9	1.1	13.8	0.4	1.5	0.0	1.7	4.9	1.5	5.7
65TH 0443	0.0	0.2	11.6	0.4	13.1	0.2	0.4	0.0	1.1	3.8	1.7	4.5
65TH 0449	0.2	0.0	8.2	0.9	10.0	0.4	0.0	0.0	0.7	5.8	1.6	3.8
65TH 0453	0.0	0.2	9.5	0.5	18.1	1.8	0.7	0.0	0.9	3.8	1.6	4.3
65TH 0455	0.0	0.4	12.2	1.1	13.1	1.1	0.9	0.0	0.9	5.1	2.7	5.1
65TH 0456	0.2	0.0	10.7	0.0	13.6	1.8	1.1	0.0	0.4	2.2	0.9	3.6
65TH 0459	0.0	0.2	9.5	2.3	11.5	0.9	0.9	0.2	0.2	3.7	3.2	3.9
65TH 0461	0.4	0.0	11.6	1.7	21.6	0.7	0.2	0.0	1.1	3.6	4.4	5.2
65TH 0463	0.0	0.0	13.1	0.5	28.2	0.2	0.0	0.0	0.2	5.1	1.4	7.0
65TH 0464	0.0	0.0	17.1	1.1	16.7	0.4	2.0	0.0	0.2	3.6	2.3	5.6
65TH 0466	0.2	0.2	12.4	1.3	15.6	0.4	1.8	0.0	1.6	3.6	2.4	6.3
65TH 0468	0.2	0.2	11.3	0.9	18.7	0.4	0.9	0.0	0.7	3.6	0.7	3.5
65TH 0475	0.2	1.8	10.4	1.6	14.2	1.1	4.7	0.0	0.7	4.4	1.3	4.9
65TH 0476	0.0	0.0	10.9	3.4	20.6	0.5	4.3	0.0	0.5	3.2	1.8	5.0
65TH 0477	0.0	0.2	19.4	0.9	16.8	2.3	1.2	0.0	0.0	4.6	1.4	3.7
65TH 0480	0.2	0.2	13.1	6.1	11.3	0.9	1.4	0.0	0.5	4.5	0.2	4.0
65TH 0482	0.7	0.0	8.9	0.9	20.2	1.3	2.0	0.0	2.2	4.7	2.2	3.8
65TH 0484	0.0	0.4	12.9	1.8	10.4	0.2	2.2	0.0	1.1	3.3	0.7	4.4
65TH 0486	0.0	0.7	12.4	0.9	17.6	1.6	1.4	0.0	0.5	8.1	2.9	4.7
65TH 0502	0.2	0.0	7.1	2.2	7.1	0.4	5.5	0.0	0.7	3.3	1.1	4.3
65TH 0514	0.4	0.2	5.9	0.9	5.3	0.2	0.7	1.1	0.2	2.4	0.7	4.5
65TH 0532	0.0	0.0	8.4	0.4	12.2	0.2	3.6	0.4	0.9	6.7	3.8	4.0
65TH 0544	0.4	0.0	9.8	1.1	9.6	0.7	6.9	0.9	0.9	2.9	2.7	4.6
65TH 0555	0.0	0.0	11.1	0.2	8.6	0.9	1.8	0.2	0.2	7.3	1.3	2.7
71MLA0002	0.0	0.3	19.7	0.0	20.0	0.3	0.0	0.0	0.0	3.5	3.5	4.1
71MLA0003	0.0	0.7	20.0	0.0	21.0	0.0	0.0	0.0	0.0	2.3	1.5	4.2
71MLA0004	0.0	0.3	24.2	0.0	27.4	0.0	0.0	0.0	0.0	2.5	3.1	3.0
71MLB0002	0.0	0.5	14.7	0.0	17.3	0.8	0.5	0.0	0.0	3.3	3.0	2.5
71MLB0003	0.0	0.5	14.7	0.0	11.5	0.3	0.0	0.0	0.0	5.5	4.3	3.9
71MLC0001	0.0	0.5	11.9	0.0	7.6	0.2	0.2	0.0	0.0	3.5	3.5	6.7
71MLC0004	0.0	0.3	10.0	0.0	5.8	0.3	0.5	0.0	0.5	4.0	0.8	3.7
71MLD0002	1.0	0.0	13.3	0.0	6.0	0.0	0.5	0.0	0.0	2.8	1.5	5.7
71MLD0003	0.0	19.0	10.0	0.0	3.0	0.0	0.3	0.0	0.0	2.0	2.3	1.7
71MLD0004	0.0	8.3	12.3	0.0	3.2	0.0	0.0	0.0	0.5	5.3	1.2	3.5
71MLD0006	0.0	0.0	16.0	0.0	4.5	0.0	0.5	0.0	0.5	7.0	3.8	4.2
71MLF0009	0.0	0.0	7.8	0.0	2.8	0.3	54.8	0.0	0.0	1.3	2.5	0.8
71MLG0001	0.8	0.3	13.3	0.3	3.5	1.0	8.8	0.0	1.8	2.8	1.3	5.5
71MLH0002	0.3	7.8	14.7	0.0	15.0	0.5	3.5	0.0	0.0	2.5	2.5	5.8
71MLH0004	0.0	0.0	12.5	0.0	6.8	0.5	2.5	0.0	0.5	4.5	3.0	4.0
71MLH0006	0.5	0.0	1.3	0.0	5.8	0.8	3.2	0.0	0.0	6.5	2.2	1.6
71MLH0008	0.0	0.0	18.0	0.0	8.3	0.5	1.0	0.0	0.0	3.3	2.8	3.3
71MLH0009	0.5	0.0	10.8	0.0	7.8	0.0	2.5	0.0	0.2	4.2	1.7	3.2
71MLI0002	0.0	0.0	14.9	0.0	8.4	0.3	1.9	0.0	0.5	5.0	2.0	3.5

Sample	Mon	Pyr	Dio	Aug	Hyp	Rut	Sid	Spi	Sta	Tit	Zir	Other
71ML10003	0.5	0.0	10.8	1.3	10.3	0.0	3.8	0.0	0.0	5.0	3.8	3.5
71ML10004	0.0	1.8	7.5	1.3	6.8	0.3	7.1	0.0	0.0	3.0	1.5	5.6
71ML10006	0.0	1.0	11.2	0.0	8.0	0.0	8.3	0.0	0.8	2.8	1.3	3.2
71MLJ0001	0.0	1.8	14.3	3.0	9.8	0.5	2.3	0.0	0.0	5.1	2.5	3.1
71MLK0004	0.8	7.3	13.8	1.5	9.8	0.5	2.8	0.0	0.5	2.8	2.0	3.6
71MLK0005	0.5	9.3	13.0	10.0	12.3	0.0	1.0	0.3	0.0	2.5	2.8	6.0
71MLL0001	0.5	18.0	13.0	0.8	9.8	0.0	1.8	0.0	0.0	4.0	2.5	7.2
71MLL0005	0.5	7.3	10.5	0.5	13.3	0.0	2.5	0.0	0.3	2.3	1.8	6.2
71MLL0009	0.8	6.5	11.7	0.5	10.3	0.8	1.8	0.0	1.0	2.5	2.0	6.3
71MLM0001	0.0	4.8	8.0	0.5	5.0	0.5	0.8	0.3	0.0	1.0	2.5	1.1
71MLM0004	0.8	4.3	14.0	1.5	10.3	0.0	1.0	0.0	1.3	1.8	2.3	4.1
71MLN0002	0.8	0.0	19.8	0.8	15.3	0.0	0.0	0.0	1.8	1.3	2.8	8.3
71MLN0004	5.0	0.3	31.5	0.5	20.5	0.0	0.3	0.0	1.5	3.3	1.8	4.5
71MLN0005	6.3	0.0	33.8	0.5	19.3	0.0	0.0	0.0	0.3	1.5	2.3	6.6

APPENDIX G
Geochemical Analyses, Hudson Bay
 (<0.002mm fraction)

Analysis: Bondar-Clegg and Company Ltd.
 D.C. Plasma
 Total Acid Dissolution: Hf-HClO₄-HNO₃-HCl
 Total no. of analyses: 116

TABLE 1

Detection Limits: Mg Magnesium 0.001 PCT
 Co Cobalt 1 PPM
 Al Aluminium 0.001 PCT
 K Potassium 0.001 PCT
 Ca Calcium 0.001 PCT
 Fe Iron 0.001 PCT
 Cr Chromium 1 PPM

Sample Number	Mg (pct)	Co (ppm)	Al (pct)	K (pct)	Ca (pct)	Fe (pct)	Cr (ppm)
65TH 0046	2.200	27	5.350	3.060	2.250	4.700	171
65TH 0055	2.840	30	7.710	3.410	1.590	5.450	169
65TH 0064	2.890	28	7.080	3.510	2.110	5.360	170
65TH 0066	2.920	27	6.710	3.410	1.990	5.170	205
65TH 0080	2.450	22	6.030	3.290	1.070	4.920	186
65TH 0082	2.700	21	6.580	3.260	1.100	4.960	164
65TH 0086	2.550	22	6.030	3.190	1.240	4.820	159
65TH 0088	2.500	21	6.190	3.000	1.250	4.700	158
65TH 0090	2.300	26	8.300	3.500	1.250	5.080	153
65TH 0120	2.360	19	5.420	3.140	1.030	4.500	133
65TH 0130	2.150	21	5.890	3.270	1.910	5.030	163
65TH 0132	2.360	20	6.380	3.320	1.490	4.630	169
65TH 0134	2.700	24	6.120	3.420	1.380	5.080	167
65TH 0137	2.610	23	5.760	3.180	1.650	5.170	168
65TH 0146	2.570	22	5.250	3.300	1.090	5.150	166
65TH 0150	2.460	21	5.710	3.300	1.240	4.760	164
65TH 0152	2.310	29	8.540	3.280	1.830	5.380	155
65TH 0166	2.330	35	5.240	3.170	1.460	4.950	119
65TH 0174	2.610	22	6.860	3.100	1.940	4.640	154
65TH 0178	2.620	16	6.930	2.680	2.020	4.170	123
65TH 0180	2.620	16	9.400	2.660	1.880	4.200	122
65TH 0180	2.760	18	7.910	2.960	2.240	4.300	142
65TH 0186	2.510	23	5.730	3.070	1.490	4.920	164
65TH 0191	3.080	30	7.850	3.730	1.200	6.340	236
65TH 0218	2.160	13	6.080	2.260	2.140	3.340	99
65TH 0224	3.930	21	7.630	3.210	2.620	5.130	108
65TH 0226	2.490	26	5.760	3.550	2.770	4.920	157
65TH 0228	2.360	32	6.500	3.180	1.390	4.620	151
65TH 0228	2.300	18	6.680	2.720	2.020	4.090	120

Sample Number	Mg (pct)	Co (ppm)	Al (pct)	K (pct)	Ca (pct)	Fe (pct)	Cr (ppm)
65TH 0230	2.690	29	6.820	3.210	2.180	5.080	154
65TH 0232	3.860	28	8.270	3.360	2.080	5.730	148
65TH 0234	2.570	38	7.720	3.350	1.620	4.920	144
65TH 0236	2.380	37	8.900	3.410	1.580	4.840	150
65TH 0238	3.000	30	7.690	3.480	1.720	5.750	130
65TH 0244	2.880	47	7.680	3.510	2.190	5.600	142
65TH 0244	3.080	31	6.310	3.770	1.450	6.100	145
65TH 0250	2.990	31	6.880	3.840	1.570	5.870	141
65TH 0252	2.630	26	5.900	3.300	1.460	5.210	122
65TH 0254	2.900	26	7.130	3.550	1.700	5.370	141
65TH 0258	2.660	25	6.240	3.390	1.450	5.080	135
65TH 0260	2.500	27	5.000	3.420	1.360	5.190	148
65TH 0268	2.250	14	6.350	2.150	4.200	3.900	112
65TH 0272	2.400	30	5.830	3.130	1.330	4.550	152
65TH 0272	2.770	27	6.100	3.630	1.550	5.770	157
65TH 0274	2.300	23	6.430	3.010	1.310	4.510	138
65TH 0280	2.740	26	5.670	3.160	1.700	4.920	150
65TH 0282	2.560	31	6.030	3.210	1.390	4.940	153
65TH 0284	2.580	27	5.640	3.430	1.410	4.850	142
65TH 0288	2.690	27	6.250	3.330	1.700	4.870	137
65TH 0290	2.830	33	6.710	3.780	1.460	5.760	159
65TH 0292	2.850	29	6.820	3.410	1.520	5.490	124
65TH 0296	3.120	34	5.720	3.530	1.490	5.900	162
65TH 0300	2.770	30	6.300	3.700	1.800	5.430	145
65TH 0302	2.690	27	5.720	3.530	1.590	6.300	137
65TH 0304	2.620	30	5.850	3.430	1.400	5.480	128
65TH 0320	2.650	21	5.810	3.340	1.050	5.130	167
65TH 0326	2.600	21	5.690	3.350	1.110	5.090	170
65TH 0328	2.680	22	5.940	3.380	1.170	4.910	183
65TH 0330	2.680	18	6.160	3.140	1.240	4.880	158
65TH 0332	2.830	22	5.900	3.330	1.120	5.360	173
65TH 0336	2.770	24	4.900	3.350	1.730	5.130	150
65TH 0338	2.570	28	6.230	3.200	1.760	5.820	156
65TH 0340	3.160	26	6.800	3.220	1.820	5.500	148
65TH 0342	3.100	30	6.700	3.320	1.860	5.830	153
65TH 0344	3.070	26	6.340	3.430	1.970	5.410	154
65TH 0348	2.640	25	5.110	2.960	1.560	4.550	161
65TH 0352	2.890	32	6.420	3.580	1.790	5.910	156
65TH 0354	2.820	33	6.750	3.430	2.020	5.930	146
65TH 0360	1.370	28	3.150	1.690	.800	2.680	130
65TH 0362	2.650	53	6.790	3.520	1.470	5.650	140
65TH 0366	2.710	39	6.430	3.270	1.680	5.440	126
65TH 0370	2.800	30	6.460	3.430	1.690	5.230	150
65TH 0371	2.200	16	4.790	2.880	3.300	3.940	127
65TH 0382	3.310	15	7.300	2.540	5.540	3.290	112
65TH 0398	2.440	16	5.280	2.760	3.680	4.190	163
65TH 0402	2.360	19	4.950	3.000	3.220	4.500	166
65TH 0406	2.590	26	5.800	3.110	2.210	4.770	155

Sample Number	Mg (pct)	Co (ppm)	Al (pct)	K (pct)	Ca (pct)	Fe (pct)	Cr (ppm)
65TH 0408	2.440	20	5.060	2.910	3.400	4.660	139
65TH 0408	2.620	26	6.010	3.100	2.150	4.920	155
65TH 0410	2.770	30	6.230	3.190	2.080	5.100	144
65TH 0412	2.700	26	6.280	3.000	2.330	4.790	145
65TH 0418	2.950	28	6.580	3.180	2.210	5.280	147
65TH 0420	2.760	26	5.970	3.090	2.260	4.850	153
65TH 0426	2.830	27	6.400	3.360	2.500	5.140	156
65TH 0434	2.640	31	6.630	3.490	1.630	5.440	148
65TH 0436	2.860	31	6.090	3.410	1.630	5.630	142
65TH 0438	2.710	28	5.950	3.360	1.790	5.060	143
65TH 0440	2.750	34	6.590	3.630	1.690	5.420	152
65TH 0444	2.410	39	5.980	3.610	1.490	4.530	129
65TH 0448	3.440	38	9.790	4.960	1.770	6.750	181
65TH 0452	2.250	38	6.420	3.930	1.210	4.740	155
65TH 0454	2.280	37	6.070	3.860	1.220	4.680	146
65TH 0458	2.260	38	6.430	3.860	.990	4.960	127
65TH 0462	1.970	23	6.270	3.370	1.180	4.000	125
65TH 0464	2.180	27	6.520	3.710	1.200	4.390	152
65TH 0466	2.190	27	5.910	3.760	.960	4.760	149
65TH 0468	2.180	27	5.670	3.810	.890	4.610	145
65TH 0470	2.210	32	5.450	3.820	.960	4.880	150
65TH 0474	2.710	26	8.890	3.740	1.480	5.890	170
65TH 0480	2.600	28	7.730	3.560	1.540	5.590	164
65TH 0482	2.580	29	7.450	3.690	1.210	5.310	175
65TH 0484	2.580	24	7.120	3.670	1.130	5.220	176
65TH 0486	2.240	31	7.650	3.780	2.670	5.520	160
65TH 0488	2.530	35	7.280	3.910	1.080	5.320	171
65TH 0490	2.570	26	7.120	3.790	1.180	5.150	166
65TH 0498	2.470	22	7.010	3.580	1.690	5.030	162
65TH 0500	2.410	21	7.400	3.420	1.540	4.780	174
65TH 0502	2.290	23	7.710	3.220	4.110	5.170	143
65TH 0508	3.920	30	7.750	3.660	2.090	7.500	274
65TH 0514	2.510	24	8.320	3.580	2.430	5.330	163
65TH 0523	2.330	15	6.860	2.780	3.310	3.670	124
65TH 0538	2.620	26	7.300	3.350	2.120	4.470	153
65TH 0548	2.850	31	7.920	3.480	1.930	5.120	161
65TH 0550	2.780	33	7.570	3.280	1.680	5.400	161
65TH 0560	2.550	24	6.600	3.480	1.540	4.870	155
65TH 0566	2.750	27	7.360	3.270	1.860	5.340	159
Max. Value:	3.930	53	9.790	4.960	5.540	7.500	274
Min. Value:	1.370	13	3.150	1.690	0.800	2.680	99
Arith. Mean:	2.637	26	6.590	3.370	1.720	4.840	146

TABLE 2

Detection Limits: Mn Manganese 0.001 PCT
 Ni Nickel 1 PPM
 Cu Copper 1 PPM
 Zn Zinc 1 PPM
 As Arsenic 5 PPM
 Mo Molybdenum 1 PPM
 Pb Lead 5 PPM

Sample Number	MN (pct)	NI (ppm)	Cu (ppm)	Zn (ppm)	As (ppm)	Mo (ppm)	Pb (ppm)
65TH 0046	.070	76	36	173	2	1	42
65TH 0055	.090	83	40	203	2	2	38
65TH 0064	.060	77	75	183	2	4	44
65TH 0066	.050	76	47	182	2	3	41
65TH 0080	.050	74	70	168	2	3	43
65TH 0082	.050	79	37	157	2	0.5	36
65TH 0086	.050	69	45	155	2	2	30
65TH 0088	.050	67	36	151	2	2	30
65TH 0090	.060	77	50	154	2	3	40
65TH 0120	.050	64	68	147	2	4	32
65TH 0130	.060	69	28	164	2	4	41
65TH 0132	.050	68	170	178	2	3	40
65TH 0134	.050	70	90	182	2	3	40
65TH 0137	.060	80	58	170	2	5	37
65TH 0146	.050	72	122	181	2	4	40
65TH 0150	.050	68	56	159	2	3	38
65TH 0152	.140	71	53	163	2	4	44
65TH 0166	.450	85	38	168	2	6	37
65TH 0174	.050	65	47	157	2	2	35
65TH 0178	.040	56	59	135	2	3	31
65TH 0180	.050	69	33	130	2	4	35
65TH 0180	.050	61	68	138	2	3	35
65TH 0186	.060	77	33	175	2	3	41
65TH 0191	.070	96	58	178	2	4	41
65TH 0218	.050	51	22	112	2	4	32
65TH 0224	.060	69	37	158	2	2	46
65TH 0226	.050	71	84	177	2	3	43
65TH 0228	.140	73	41	171	2	2	34
65TH 0228	.040	55	33	133	2	0.5	34
65TH 0230	.080	74	37	168	2	2	40
65TH 0232	.100	77	39	188	2	3	44
65TH 0234	.450	98	41	156	2	12	44
65TH 0236	.420	103	39	166	2	10	55
65TH 0238	.210	85	36	196	7	2	44
65TH 0244	.510	86	31	159	17	6	51
65TH 0244	.170	88	36	193	8	4	49
65TH 0250	.170	85	34	184	10	3	43
65TH 0252	.120	64	34	165	7	4	35

Sample Number	Mn (pct)	Ni (ppm)	Cu (ppm)	Zn (ppm)	As (ppm)	Mo (ppm)	Pb (ppm)
65TH 0254	.070	72	43	185	5	4	40
65TH 0258	.060	66	29	174	10	2	36
65TH 0260	.120	66	30	180	2	5	34
65TH 0268	.040	58	24	140	2	4	34
65TH 0272	.070	71	35	170	2	4	30
65TH 0272	.080	76	35	166	2	3	39
65TH 0274	.060	66	31	149	2	4	27
65TH 0280	.070	69	36	161	2	2	32
65TH 0282	.090	75	35	181	2	4	31
65TH 0284	.060	71	33	188	5	4	32
65TH 0288	.070	67	38	179	2	1	29
65TH 0290	.160	77	33	196	5	3	41
65TH 0292	.060	79	35	187	2	1	37
65TH 0296	.160	88	39	185	2	2	55
65TH 0300	.170	85	38	161	2	2	41
65TH 0302	.100	75	49	168	7	1	39
65TH 0304	.160	75	35	177	8	1	36
65TH 0320	.060	70	38	161	2	1	36
65TH 0326	.050	64	35	157	7	2	41
65TH 0328	.050	65	70	158	6	2	81
65TH 0330	.060	64	32	142	2	2	84
65TH 0332	.060	66	43	159	2	7	37
65TH 0336	.060	62	38	162	2	2	35
65TH 0338	.070	64	28	167	5	2	52
65TH 0340	.060	64	40	174	2	2	34
65TH 0342	.120	65	36	165	5	2	40
65TH 0344	.080	64	42	170	9	3	48
65TH 0348	.050	67	39	164	2	4	38
65TH 0352	.200	81	60	204	2	2	49
65TH 0354	.220	78	38	173	2	4	47
65TH 0360	.070	79	32	171	2	2	137
65TH 0362	1.000	107	37	168	7	11	52
65TH 0366	.790	85	35	165	2	10	42
65TH 0370	.100	86	50	191	9	2	44
65TH 0371	.040	51	29	137	2	5	35
65TH 0382	.040	54	38	120	2	4	38
65TH 0398	.040	57	39	137	2	1	43
65TH 0402	.050	58	36	150	2	2	44
65TH 0406	.070	70	36	163	2	2	44
65TH 0408	.050	59	31	143	2	4	42
65TH 0408	.070	69	33	163	2	2	67
65TH 0410	.080	71	36	167	2	2	44
65TH 0412	.060	67	34	159	2	3	92
65TH 0418	.120	68	36	161	2	1	50
65TH 0420	.080	67	36	157	2	3	49
65TH 0426	.070	69	38	161	2	4	42
65TH 0434	.210	83	36	164	11	5	45

Sample Number	Mn (pct)	Ni (ppm)	Cu (ppm)	Zn (ppm)	As (ppm)	Mo (ppm)	Pb (ppm)
65TH 0436	.120	79	37	181	2	4	42
65TH 0438	.070	78	38	175	2	3	48
65TH 0440	.200	84	37	177	2	4	54
65TH 0444	.350	96	35	155	2	5	48
65TH 0448	.400	90	37	210	8	3	73
65TH 0452	.290	99	34	109	2	6	58
65TH 0454	.250	95	35	180	2	5	60
65TH 0458	.270	89	36	170	2	6	50
65TH 0462	.080	62	27	143	2	8	39
65TH 0464	.060	73	32	160	2	4	49
65TH 0466	.060	81	35	174	77	2	51
65TH 0468	.050	76	31	172	2	3	50
65TH 0470	.090	84	36	180	2	3	62
65TH 0474	.070	80	37	182	2	3	45
65TH 0480	.060	79	34	168	2	5	55
65TH 0482	.060	79	38	181	2	3	59
65TH 0484	.060	63	30	172	2	2	48
65TH 0486	.070	82	35	179	2	1	51
65TH 0488	.090	83	35	196	2	2	54
65TH 0490	.060	74	35	174	2	3	50
65TH 0498	.060	72	29	156	2	4	52
65TH 0500	.050	73	35	156	2	2	55
65TH 0502	.060	69	29	150	2	2	64
65TH 0508	.080	97	47	227	9	3	87
65TH 0514	.060	72	33	159	2	4	49
65TH 0523	.040	52	29	121	2	3	31
65TH 0538	.050	71	35	166	2	3	43
65TH 0548	.080	79	37	179	2	2	46
65TH 0550	.100	79	36	179	2	6	45
65TH 0560	.070	60	28	150	2	3	37
65TH 0566	.120	73	36	161	2	4	48
Max. value:	1.000	107	170	227	77	12	137
Min. value:	.040	51	22	109	2	0.5	27
Arith mean:	.090	71	40	157			43

APPENDIX H

Mineralogy of Clay-size Fraction

13 Analysis

Cal - calcite Amph - amphibole
 Dol - dolomite Ill - illite
 Feld - feldspars Kao - kaolinite
 Qtz - quartz Chl - chlorite
 Sm - smectite

No relative abundance given
 x mineral present
 tr slight indication
 - undetected

Sample	Cal	Dol	Feld	Qtz	Amph	Ill	Kao	Chl	Sm
65 TH									
082	-	tr	x	x	tr	x	x	x	-
166	-	x	x	x	-	x	x	x	tr(?)
174	-	x	x	x	tr	x	x	x	-
250	-	x	x	x	tr	x	x	x	tr(?)
268	x	x	x	x	tr	x	x	tr	-
274	-	-	x	x	-	x	x	x	-
282	-	tr	x	x	-	x	x	x	tr(?)
338	-	x	x	x	tr	x	x	x	tr(?)
344	-	x	x	x	-	x	x	x	-
352	-	x	x	x	-	x	x	x	x
371	x	x	x	x	-	x	x	x	tr(?)
456	-	x	x	x	-	x	x	x	tr(?)
500	-	x	x	x	tr	x	x	x	tr(?)

APPENDIX I
Leco Carbonate Determinations, Hudson Bay

Analysis: Terrain Science Division, GSC.
 Leco Induction Furnace
 Size Fraction: <0.063mm
 Total no. Analyses: 140

Sample Number	Total Carb %	Non Carb %	Carb %	CaCo3 Equiv %
65TH 0046	5.56	.35	5.21	43.42
65TH 0055	3.02	.67	2.35	19.58
65TH 0064	4.00	.68	3.32	27.67
65TH 0066	4.16	.74	3.42	28.50
65TH 0080	2.30	.79	1.51	12.58
65TH 0082	1.94	.53	1.41	11.75
65TH 0084	2.25	.75	1.50	12.50
65TH 0086	2.16	.67	1.49	12.42
65TH 0088	1.82	.45	1.37	11.42
65TH 0090	1.03	.32	.71	5.92
65TH 0120	1.92	.72	1.20	10.00
65TH 0130	2.13	.60	1.53	12.75
65TH 0132	3.22	.69	2.53	21.08
65TH 0134	2.85	.75	2.10	17.50
65TH 0137	2.41	.56	1.85	15.42
65TH 0138	3.29	.52	2.77	23.08
65TH 0146	2.76	.73	2.03	16.92
65TH 0150	3.01	.87	2.14	17.83
65TH 0152	3.61	.52	3.09	25.75
65TH 0166	2.86	.43	2.43	20.25
65TH 0174	5.06	.68	4.38	36.50
65TH 0178	5.01	1.00	4.01	33.42
65TH 0180A	5.36	.89	4.47	37.25
65TH 0180B	3.90	.70	3.20	26.67
65TH 0186	1.27	.28	.99	8.25
65TH 0191	1.68	.34	1.34	11.17
65TH 0192	5.62	.82	4.80	40.00
65TH 0212	1.75	.95	.80	6.67
65TH 0214	3.09	1.18	1.91	15.92
65TH 0216	2.98	1.07	1.91	15.92
65TH 0218	2.22	.83	1.39	11.58
65TH 0220	1.88	.77	1.11	9.25
65TH 0224	4.85	.82	4.03	33.58
65TH 0226	5.52	.52	5.00	41.67
65TH 0228A	1.61	.60	1.01	8.42
65TH 0228B	5.21	.84	4.37	36.42
65TH 0230	3.78	.59	3.19	26.58
65TH 0232	3.02	.58	2.44	20.33
65TH 0234	2.67	.30	2.37	19.75

Sample Number	Total Carb %	Non Carb %	Carb %	CaCo3 Equiv %
65TH 0236	2.80	.27	2.53	21.08
65TH 0238	2.31	.62	1.69	14.08
65TH 0244A	2.80	.41	2.39	19.92
65TH 0244B	3.58	.36	3.22	26.83
65TH 0250	3.19	.43	2.76	23.00
65TH 0252	2.97	.34	2.63	21.92
65TH 0254	3.07	.41	2.66	22.17
65TH 0258	2.78	.66	2.12	17.67
65TH 0260	2.50	.56	1.94	16.17
65TH 0264	2.89	.58	2.31	19.25
65TH 0268	3.24	1.38	1.86	15.50
65TH 0272A	1.63	.74	.89	7.42
65TH 0272B	3.18	.61	2.57	21.42
65TH 0274	1.26	.72	.54	4.50
65TH 0280	3.00	.79	2.21	18.42
65TH 0282	1.85	.79	1.06	8.83
65TH 0284	2.23	.66	1.57	13.08
65TH 0286	2.15	.66	1.49	12.42
65TH 0288	3.09	.52	2.57	21.42
65TH 0290	2.71	.39	2.32	19.33
65TH 0292	2.62	.55	2.07	17.25
65TH 0296	3.77	.26	3.51	29.25
65TH 0300	4.33	.34	3.99	33.25
65TH 0302	2.38	.50	1.88	15.67
65TH 0304	2.37	.74	1.63	13.58
65TH 0320	2.76	.63	2.13	17.75
65TH 0324	2.44	.72	1.72	14.33
65TH 0326	2.70	.76	1.94	16.17
65TH 0328	2.66	.84	1.82	15.17
65TH 0330	2.35	.60	1.75	14.58
65TH 0332	2.39	.69	1.70	14.17
65TH 0336	3.24	.89	2.35	19.58
65TH 0338	3.92	.49	3.43	28.58
65TH 0340	3.15	.49	2.66	22.17
65TH 0342	3.42	.61	2.81	23.42
65TH 0344	3.69	.68	3.01	25.08
65TH 0346	3.39	.66	2.73	22.75
65TH 0348	3.70	.74	2.96	24.67
65TH 0350	3.91	.91	3.00	25.00
65TH 0352	3.26	.62	2.64	22.00
65TH 0354	3.05	.35	2.70	22.50
65TH 0360	2.24	.76	1.48	12.33
65TH 0362	2.34	.57	1.77	14.75
65TH 0366	2.47	.60	1.87	15.58
65TH 0368	3.13	.58	2.55	21.25
65TH 0369	2.71	.67	2.04	17.00
65TH 0370	2.87	.51	2.36	19.67

Sample Number	Total Carb %	Non Carb %	Carb %	CaCo3 Equiv %
65TH 0371	7.16	.49	6.67	55.58
65TH 0378	7.23	.56	6.67	55.58
65TH 0382	6.65	.52	6.13	51.08
65TH 0398	7.09	.82	6.27	52.25
65TH 0402	6.38	.73	5.65	47.08
65TH 0406	4.38	.54	3.84	32.00
65TH 0408A	3.92	.67	3.25	27.08
65TH 0408B	6.08	.63	5.45	45.42
65TH 0410	4.09	.56	3.53	29.42
65TH 0412	4.29	.52	3.77	31.42
65TH 0418	4.62	.61	4.01	33.42
65TH 0420	4.87	.72	4.15	34.58
65TH 0424	6.64	.50	6.14	51.17
65TH 0426	5.28	.61	4.67	38.92
65TH 0434	3.41	.43	2.98	24.83
65TH 0436	2.82	.70	2.12	17.67
65TH 0438	3.74	.58	3.16	26.33
65TH 0440	3.22	.49	2.73	22.75
65TH 0444	3.26	.33	2.93	24.42
65TH 0448	2.34	.54	1.80	15.00
65TH 0452	4.23	.35	3.88	32.33
65TH 0454	4.04	.26	3.78	31.50
65TH 0456	3.79	.37	3.42	28.50
65TH 0458	2.40	.53	1.87	15.58
65TH 0464	3.21	.58	2.63	21.92
65TH 0466	2.42	.48	1.94	16.17
65TH 0468	2.79	.57	2.22	18.50
65TH 0470	2.74	.62	2.12	17.67
65TH 0474	2.42	.39	2.03	16.92
65TH 0476	4.37	.40	3.97	33.08
65TH 0480	3.94	.58	3.36	28.00
65TH 0481	3.00	.75	2.25	18.75
65TH 0482	2.98	.64	2.34	19.50
65TH 0484	2.66	.65	2.01	16.75
65TH 0486	3.57	.42	3.15	26.25
65TH 0488	2.67	.71	1.96	16.33
65TH 0490	3.32	.61	2.71	22.58
65TH 0496	3.67	.55	3.12	26.00
65TH 0500	3.96	.17	3.79	31.58
65TH 0502	4.73	.52	4.21	35.08
65TH 0504	3.96	.48	3.48	29.00
65TH 0505	3.80	.42	3.38	28.17
65TH 0508	3.46	.46	3.00	25.00
65TH 0510	2.64	.59	2.05	17.08
65TH 0512	3.18	.53	2.65	22.08
65TH 0514	3.07	.57	2.50	20.83
65TH 0520	2.42	.34	2.08	17.33

Sample Number	Total Carb %	Non Carb %	Carb %	CaCo3 Equiv %
65TH 0523	6.35	.52	5.83	48.58
65TH 0538	5.40	.60	4.80	40.00
65TH 0548	4.17	.73	3.44	28.67
65TH 0550	3.51	.80	2.71	22.58
65TH 0560	1.22	.61	.61	5.08
65TH 0566	2.83	.78	2.05	17.08
65TH 0594	3.77	.59	3.18	26.50

APPENDIX J

Trend Surface Analysis of Heavy Mineral Data, Hudson Bay

The aim of the trend surface analysis is to establish regional trends in the distribution of specific heavy minerals. For the analysis, the study area was divided into six overlapping segments of approximately equal size and sample number, in order to eliminate edge effects (Agterberg, 1984) (Fig. J.1). Each segment was analysed separately using a trend surface analysis program (Agterberg and Chung, 1975). The program essentially describes data trends by two-dimensional polynomial equations. Goodness-of-fit is determined through analysis of variance and the results from each segment are integrated to form mineral distribution trends throughout the bay.

The output from the program consists of a series of maps illustrating polynomial surfaces of increasing degrees. Statistical evaluation of the "strength" of the trend surface is based on the analysis of variance using three tests.

1. Multiple Correlation Coefficient Squared (R^2): the sum of squares due to the trend divided by the sum of squares of the original observations, levels off as the closest fitting trend is approached.
2. Residual variance (mean square due to residuals) is at a minimum as the "best fit" trend is approached.
3. Step-wise analysis of variance using F-tests. The program converts computed F-values into the corresponding probability values. Values of 95% and over are considered statistically significant.

The results of the trend surface analyses for the six areas are summarized below for three heavy minerals (hematite, siderite and garnet). The selected trend surface is indicated by a star.

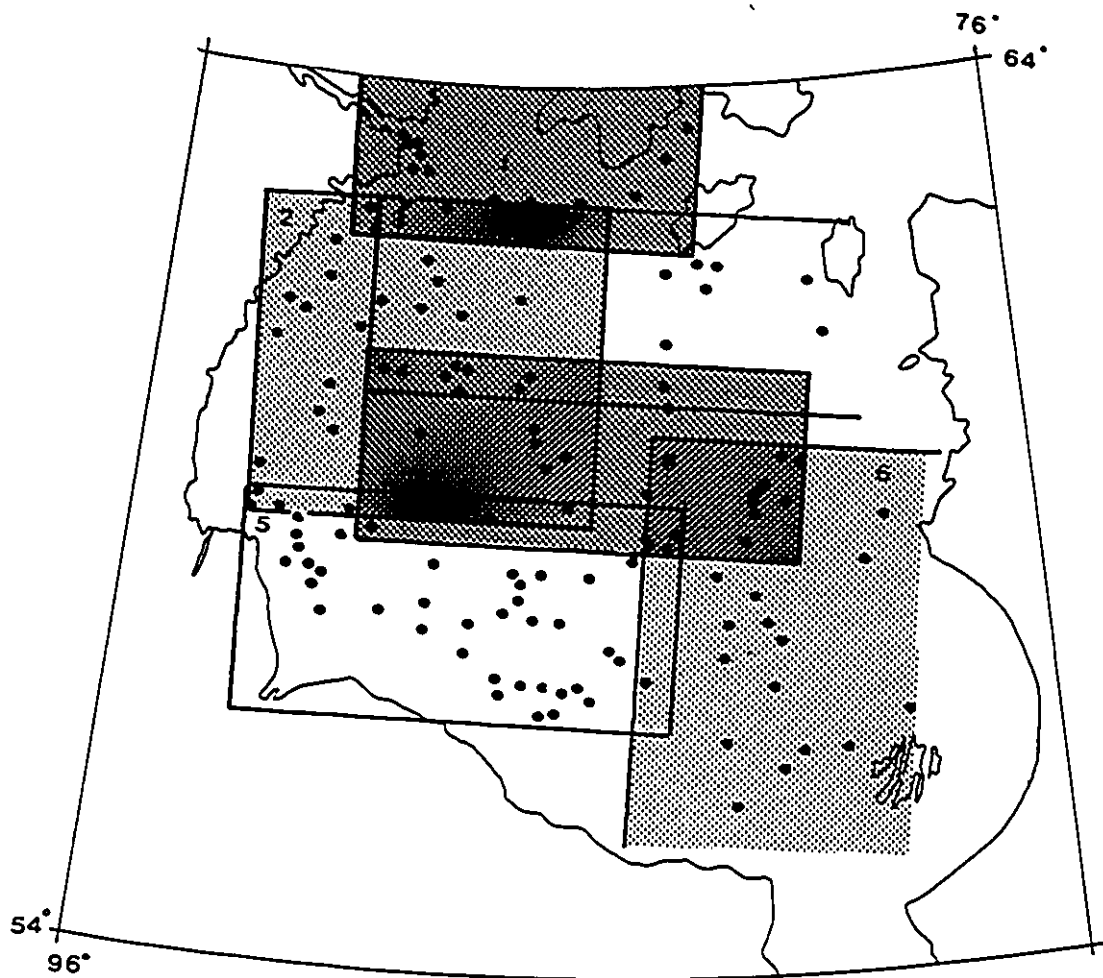


Figure J.1: Segments used in trend surface analysis of heavy minerals, Hudson Bay.

HEMATITE

Degree	R2	Residual Variance	F-test & Probability
Trend Surface 1			
1 (linear)	0.322	2.6608	96.96
2 (quadratic)	0.405	2.7969	43.79
3 (cubic)	0.760	1.5400	97.08 *
4 (quartic)	0.920	0.9280	84.71
5 (quintic)	-	-	-
Trend Surface 2			
1	0.099	15.090	86.32
2	0.114	16.120	10.07
3	0.425	11.790	99.22 *
4	0.532	11.450	65.68
Trend Surface 3			
1	0.341	8.578	99.33 *
2	0.467	7.930	79.22
3	0.598	7.380	72.08
Trend Surface 4			
1	0.049	94.640	47.78
2	0.088	102.510	19.96
3	0.340	88.700	84.70 *
Trend Surface 5			
1	0.020	48.390	35.69
2	0.080	48.790	54.19
3	0.230	45.250	84.60 *
4	0.340	44.900	59.96
Trend Surface 6			
1	0.174	84.370	90.87
2	0.395	70.240	92.79 *
3	0.452	77.710	24.38

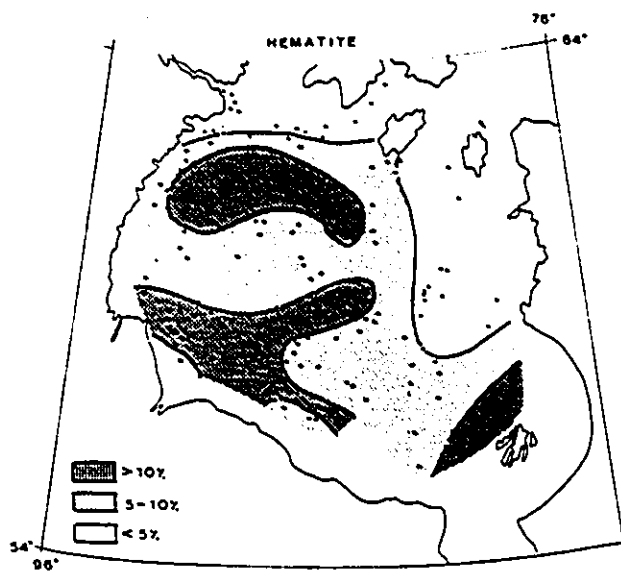
SIDERITE

Degree	R2	Residual Variance	F-test % Probability
Trend Surface 1			
1	0.152	0.706	77.29
2	0.706	0.293	99.90
3	0.902	0.134	98.90 *
4	0.950	0.124	58.21
5	-	-	-
Trend Surface 2			
1	0.025	79.395	38.24
2	0.126	77.313	72.32
3	0.153	83.550	15.59
4	0.361	76.009	80.87 *
5	0.392	94.106	1.72
Trend Surface 3			
1	0.092	107.612	68.96
2	0.186	110.365	49.25
3	0.235	128.139	10.79
Trend Surface 4			
1	0.161	100.836	89.78
2	0.233	104.202	44.98
3	0.279	118.517	12.93
Trend Surface 5			
1	0.101	28.123	89.91
2	0.287	23.980	97.53 *
3	0.405	22.254	84.49
4	0.543	19.815	87.46
5	-	-	-
Trend Surface 6			
1	0.379	1.044	99.74
2	0.410	1.125	24.51
3	0.655	0.806	96.14 *

GARNET

Degree	R2	Residual Variance	F-test % Probability
Trend Surface 1			
1	0.441	8.440	99.47 *
2	0.602	7.230	88.52
3	0.688	7.710	42.82
4	0.806	-	37.29
Trend Surface 2			
1	0.248	20.010	99.50
2	0.570	12.42	99.98 *
3	0.592	13.31	20.07
4	0.632	14.09	34.22
Trend Surface 3			
1	0.440	13.100	99.90 *
2	0.479	13.900	33.40
3	0.604	13.70	70.59
Trend Surface 4			
1	0.011	20.79	14.29
2	0.239	18.11	89.42
3	0.362	18.38	52.46
Trend Surface 5			
1	0.123	12.36	94.12
2	0.230	11.77	83.54
3	0.407	9.98	95.60 *
4	0.536	9.07	84.22
Trend Surface 6			
1	0.393	10.15	99.81 *
2	0.464	10.27	54.65
3	0.547	10.51	49.97

A.



B.

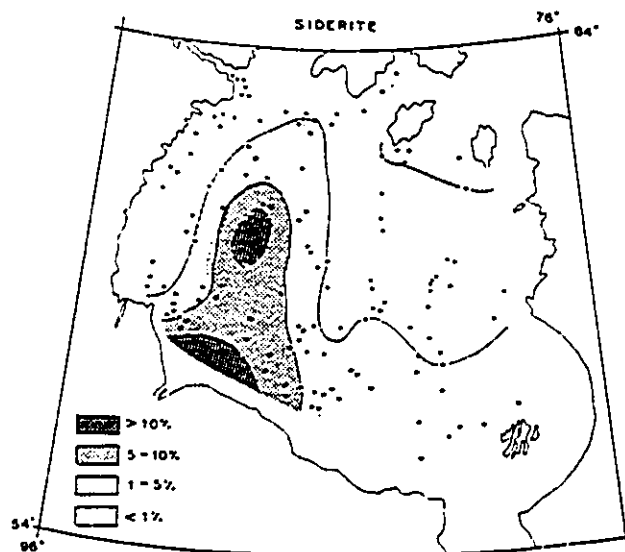


Figure J.2: Resultant trend surfaces:

A. Hematite

B. Siderite

C

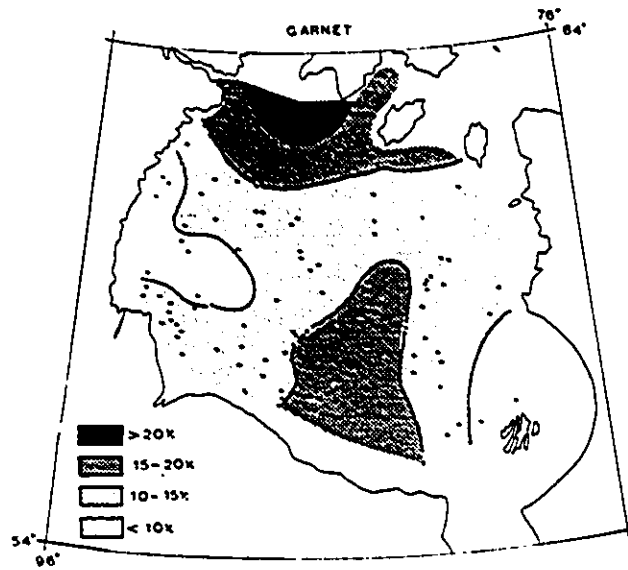


Figure J.2 (cont'd): Trend surfaces
C. Garnet

The resulting trend surfaces are shown in Figures J.2a, b,c. For each mineral, the "strength" of the trend varies for each segment. Hematite trends are statistically significant in the north but less so in the south, particularly in southwestern Hudson Bay where individual values show considerable fluctuation.

Siderite trends are significant in the north and south but are poorly defined in the central bay. In general, siderite percentages are low to zero, however, in this central area, values in excess of 50% occur at several sites. This sharp contrast affects the establishment of "good" trends, a problem which could be minimized by the use of log values.

Trend surfaces established from garnet are significant throughout the bay.