

Rocking the Continuum: A Geochemical Analysis of Palaeo-Eskimo Lithic Raw

Material Selection Strategies at the LeDx-42 Site, Southern Baffin Island

by

Anne Hamilton

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

MASTER OF ARTS

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**Rocking the Continuum: A Geochemical Analysis of Palaeo-Eskimo Lithic
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Of

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Abstract

Differential selection and use of lithic raw materials is thought to represent one of the cultural changes distinguishing the Pre-Dorset and Dorset cultures of the Canadian Arctic. This study focuses on lithic debitage from the LeDx-42 site and raw chert samples from the interior of southern Baffin Island to assess if Palaeo-Eskimo raw materials selection strategies did indeed change over time. However, the chert from this region is highly variable in colour and cannot be reliably sourced using traditional observational methods alone. Therefore, a new technique that draws on macroscopic visual, petrographic, and trace element analyses is developed to reliably determine the number of geologically unique sources available near Mingo and Amadjuak Lakes, and to assess which of them was being exploited by Palaeo-Eskimos throughout the cultural continuum.

The results of this study indicate that Palaeo-Eskimo toolmakers consistently selected toolstone from the same four geological sources throughout their 2400-year occupation of the LeDx-42 site. This implies that patterns of raw material selection did not change between the Pre-Dorset and Dorset periods at LeDx-42. Therefore, raw materials selection is not a reliable indicator of Palaeo-Eskimo culture change on southern Baffin Island and should not be used as a criterion to distinguish the Pre-Dorset and Dorset cultures.

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This thesis is dedicated in loving memory to my grandfather, Frank Hamilton

Table of Contents

Abstract	i
Acknowledgements	ii
Dedication	iv
Table of Contents	v
List of Figures	vii
List of Tables	ix
Chapter 1 Introduction	1
Project Objectives	3
Significance of Research	4
Organizational Framework	5
Chapter 2 The LeDx42 Site	8
The Amadjuak Lake District	8
Climate	10
Resources	11
Site Area and Excavation Procedures	13
Preliminary Interpretations	16
Chapter 3 Palaeo-Eskimo Archaeology and Raw Material Selection	19
The Pre-Dorset-Dorset Transition	19
Palaeo-Eskimo Culture Change and Raw Material Selection	25
Raw Material Procurement	27
Lithic Source Areas in the Arctic	32
Raw Material Selection	34
Chapter 4 The Organization of Technology	42
The Organization of Technology	42
Technological Strategies	44
Causal Factors and Choice of Technological Strategies	47
Hypotheses and Test Expectations	57
Chapter 5 Research Methodology	63
Study Samples	63
Chert Formation	65
Observational Methods	65
Geochemical Analysis	69
Research Methodology	74
Chapter Summary	80
Chapter 6 Analysis and Interpretations	81
Raw Chert Samples Analyzed	81

Debitage Samples Analyzed	82
Debitage Source Groups: Technological Attributes	94
Microscopic Analysis	99
Geochemical Analysis	103
Raw Materials: Selection Strategies	106
Raw Material Selection: An Inferential Model	114
Conclusions	119
 Chapter 7 Summary and Conclusions	 121
Summary: Research Objectives and Methodology	121
Implications of this Study for Arctic Archaeology	122
Implications of this Study for Raw Material Sourcing	124
Future Research Considerations	125
 References Cited	 127
 Appendix A	 143
Appendix B	146
Appendix C	152
Appendix D	153

List of Figures

1.1	Map of southern Baffin Island. An arrow indicates the study area and location of the LeDx-42 site (modified from Milne 2003).	4
2.1	Location of the LeDx-42 site along the south shore of the Mingo River and southwest of Amadjuak Lake (Milne 2005).	9
2.2	Picture of naturally occurring chert found near the shore of Mingo River taken in 2004 by Milne.	13
2.3	Site map of LeDx-42, Mingo Lake, Baffin Island (Milne 2005).	15
4.1	Levels of Analysis in the Organization of Technology (Nelson 1991: 59).	45
4.2	Showing the relationship between the quality and abundance of raw materials and the kinds of tools produced from them (Andrefsky 1994b:30).	57
6.1	Diagram representing the possible interconnectedness of the S1, S2, S3, and S12 source groups based of shared colour categories.	91
6.2	Diagram representing the possible interconnectedness of the S4, S5, and S12 source groups based of shared colour categories.	92
6.3	A plot using ^{27}Al vs. $^{69}\text{Ga}/^{92}\text{Zr}$ of the 17debitage source groups analyzed using SIMS.	104
6.4	A plot using ^{27}Al vs. $^{69}\text{Ga}/^{92}\text{Zr}$ of the local raw chert material and LeDx-42debitage.	108
6.5	A plot using ^{27}Al vs. $^{69}\text{Ga}/^{92}\text{Zr}$ of the raw material anddebitage source groups available during the Pre-Dorset occupation of LeDx-42.	110
6.6	A plot using ^{27}Al vs. $^{69}\text{Ga}/^{92}\text{Zr}$ of the raw material anddebitage source groups available during the Transitional occupation of LeDx-42.	111
6.7	An inferential plot of the raw materials being selected during the Pre-Dorset period at LeDx-42.	116
6.8	An inferential plot of the raw materials being selected during the Transitional period at LeDx-42.	117

6.9 An inferential plot of the raw materials being selected during the Dorset period at LeDx-42.

118

List of Tables

2.1	Radiocarbon dates from LeDx-42 (Milne 2008).	14
5.1	Colour classifications of raw samples used in the study.	75
5.2	Established colour categories used to classify lithic debitage into visual source groups.	77
6.1	Frequency and distribution of raw material texture at LeDx-42.	83
6.2	Frequency and distribution of raw material quality at LeDx-42.	83
6.3	Frequency distribution of debitage source groups at LeDx-42.	84
6.4	Frequency and distribution of raw material cortex at LeDx-42.	85
6.5	Frequency distribution of cortex cover at LeDx-42.	86
6.6	Summary of the remaining source groups including the colour and texture of raw materials, and the number of flakes with internal flaws (quality).	89
6.7	Frequency and distribution of the S1, S2, S3, and S12 debitage categories throughout the Palaeo-Eskimo culture continuum at LeDx-42.	96
6.8	Summary of the technological attributes used to determine the reduction stage of debitage selected for destructive analysis.	99

Chapter 1

Introduction

This thesis seeks to develop an innovative geochemical analytical technique to reliably identify lithic raw material sources in the Canadian Arctic, and to understand how the Palaeo-Eskimo populations living there exploited them throughout their 3000-year cultural continuum. To do this I examine raw material samples collected from the interior of southern Baffin Island, isolate their unique geochemical signatures, and conduct a comparative analysis on lithic debitage from the LeDx-42 site. The LeDx-42 site is located in the interior of the island in an area informally referred to as the 'Large Lakes District' (Stenton 1989; see Figure. 1.1). The site contains occupations spanning the entire Palaeo-Eskimo continuum; therefore, I will be able to assess how these earliest Arctic peoples were organizing their lithic technology and determine if there was a pattern or change in raw material selection strategies over time

The archaeological record is a static entity; however, the stone tools found within it were once part of a dynamic technological system (Koldehoff 1987; Nelson 1991).

Understanding how technology is organized can provide archaeologists with unique insights into peoples' past lifeways since it involves "the selection and integration of strategies for making, using, transporting, and discarding tools and the materials needed

for their manufacture and maintenance” (Nelson 1991: 57). These strategies are ultimately influenced by the surrounding environment, as well as by social and economic factors (Nelson 1991: 57). Andrefsky (1994a: 23) has suggested that the availability and quality of lithic raw materials is perhaps the most important factor influencing the organization of technology; because raw materials are not always available, toolmakers must devise strategies to help mitigate possible shortfalls when suitable toolstone is not available. The artifacts recovered by archaeologists are the direct consequences of the different strategies implemented by humans in varying circumstances. Therefore, when technology is viewed as a composite of behaviours which contribute to human adaptation, rather than simply objects used by humans to cope with external forces (Nelson 1991: 59, 62), archaeologists can make direct correlations between the material remains they recover and the populations that left them behind. The Palaeo-Eskimos relied on stone tools in every facet of their lives (Maxwell 1985), and how they procured the stone to manufacture them almost certainly influenced other aspects of their economic and social organization (Nelson 1991). It is vital to understand Palaeo-Eskimo patterns of raw material selection in order to identify if there was a shift in toolstone selectivity over time and to understand the cultural reasons that may have motivated such a change.

Some Arctic archaeologists have argued that patterns of Palaeo-Eskimo raw material selection changed over time with Dorset displaying an increased selectivity for better quality and more exotic sources compared to Pre-Dorset (e.g. Gramly 1978; Maxwell 1985; McGhee 1996; Nagy 1997). In turn, this has led some researchers to conclude that Dorset were more socially complex (e.g. McGhee 1996; Nagy 1997). However, few studies of raw material sourcing have been done in the Arctic (Gramly

1978; Lazenby 1980 for Labrador; LeBlanc 1991 for Bathurst Island; Jensen 2000 for Greenland; Cook 1995; Malyk-Selivanova *et al* 1998 for Alaska), and even fewer have used objective geochemical techniques in their analyses. (e.g. Gramly 1978; Lazenby 1980; Malyk-Selivanova *et al* 1998 for chert). Most Arctic sourcing studies have relied on the visual observation of individual material attributes (i.e. colour, texture, quality) because it is quick and inexpensive (e.g. Anderson and Hodgetts 2007; Desrosiers and Gendron 2004; LeBlanc 1996, 2000; Milne 1999, 2003). Unfortunately, these studies are hampered by subjectivity, as the classification of source groups is left to the discretion of the researcher. Chert from the interior of southern Baffin Island is especially difficult to categorize visually because it is highly variable in colour yet extremely homogeneous in quality and texture. Consequently, this toolstone is very difficult to reliably characterize using traditional observational methods alone (Milne *et al* 2007 a/b).

Project Objectives

This study has two objectives: (1) to develop a geochemical analytical technique to reliably identify lithic raw material source areas in the Canadian Arctic; and (2) to understand how the Palaeo-Eskimo populations living there exploited these sources over a 2400-year period. Drawing upon macroscopic visual, petrographic, and trace element analyses, I develop a technique to accurately source chert from the interior of southern Baffin Island. My goal is to isolate inter- and intra-source variability through the identification of distinct geochemical fingerprints. These analyses will provide more accurate insights into exactly how many raw material sources were available to the Palaeo-Eskimos in this region. Moreover, debitage analysis will allow me to assess

which sources were being used by toolmakers, and if these patterns of use changed over time.

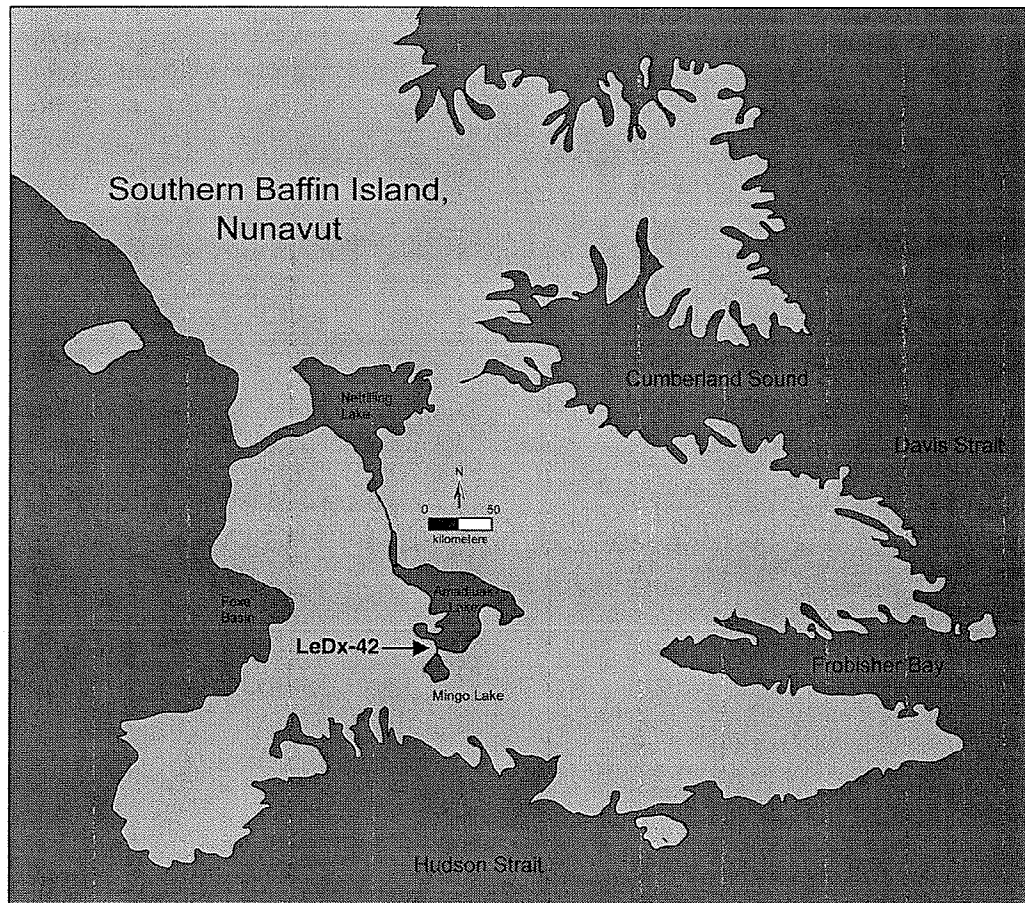


Figure 1.1 Map of southern Baffin Island. An arrow indicates the study area and location of the LeDx-42 site (modified from Milne 2003).

Significance of Research

This study represents a preliminary attempt to establish a technique to accurately source chert from the interior of southern Baffin Island. An important objective of this research is to establish the number of sources locally available in the Mingo and Amadjuak Lake districts. In turn, these data will form an important foundation upon

which I can expand this research to create a more extensive inventory of the lithic raw material sources available in the Arctic. Such an inventory could potentially revolutionize archaeological analyses and interpretations of Palaeo-Eskimo culture. Specifically, researchers would no longer have to rely on visually distinctive toolstones (e.g. Ramah Chert, Southampton Island banded chert) to study culture contact and exchange because with geochemical techniques it will be possible to study the movement of non-descript toolstones, like those found on southern Baffin Island (see Milne *et al* 2007a). Furthermore, an inventory of the sources available in the Arctic will allow archaeologists to link sites based on the presence of certain toolstones. Moreover, this study will provide archaeologists with a more definitive way to interpret Palaeo-Eskimo mobility, social interaction, trade, and cultural continuity over time.

Organizational Framework

A description of the Mingo River site, its excavation methods, artifact assemblage, and original interpretations (Milne 2005a, 2008; Milne *et al* 2008a/b) are the focus of the second chapter. Chapter 3 provides an overview of the Pre-Dorset-Dorset Transition. This is followed by a discussion of the role of lithic raw materials in Palaeo-Eskimo culture change. Finally, preferential raw material selection as it pertains to the technological and social organization of Palaeo-Eskimo culture is examined.

Chapter 4 begins with a brief summary of the Organization of Technology, and discusses in detail the different causal factors that influence the technological strategies employed by toolmakers. From this information, three working hypotheses relating to Palaeo-Eskimo raw material selection strategies are derived. These hypotheses are then

tested against locally available raw materials and the LeDx-42 lithic assemblage in order to evaluate whether or not patterns of toolstone selection changed during the Palaeo-Eskimo occupation of the site.

The research methodology used in this study is outlined in Chapter 5. The results of the macroscopic visual, petrographic, and trace element analyses are presented in Chapter 6. These data are interpreted and the observed patterns of Palaeo-Eskimo raw material selection at LeDx-42 are also discussed. Based on these interpretations, the hypotheses established in Chapter 4 are evaluated. The objectives and methods used in this study are summarized in Chapter 7, and suggestions for future research using the methods and techniques developed in this study are presented.

The results of this study indicate that patterns of lithic raw material selection remain the same throughout the Palaeo-Eskimo culture continuum. Geochemical analyses performed on debitage from the Pre-Dorset and Transitional periods indicate that four discrete sources of chert were being selected by Palaeo-Eskimos. Three of these sources are locally available while the fourth is non-local and/or exotic. Based on the data from these two early periods, inferences were made regarding patterns of selection during the Dorset period. Due to small flake size, actual samples from the Dorset component at LeDx-42 could not be thin sectioned for geochemical testing. However, based on comparisons to the categories established for the Pre-Dorset and Transitional periods, it appears that Dorset raw material selection strategies do in fact mirror those used earlier in the cultural continuum. Consequently, these results do not lend support to the prevailing notion that a shift in raw material selection strategies occurred between the Pre-Dorset and Dorset periods. Rather, it would seem that throughout the Palaeo-Eskimo

cultural continuum these peoples continued to revisit the interior region on a seasonal basis to procure locally available lithic raw material.

Chapter 2

The LeDx-42 Site

This chapter describes the LeDx-42 site and its associated artifact assemblage. To situate this discussion, I first describe the local landscape and climate characterizing the Mingo and Amadjuak Lake Districts where LeDx-42 is located.

The Amadjuak Lake District

The LeDx-42 site is situated within the Large Lakes District of southern Baffin Island. The area earns its name from the three lakes which dominate the landscape: Mingo, Amadjuak, and Nettilling. LeDx-42 is located on the southwest shore of the Mingo River where it meets the southwest shore of Amadjuak Lake (see Figure 2.1).

Amadjuak is the second largest lake in the Arctic Archipelago (after Nettilling) and is found near the eastern edge of the Foxe Lowlands. It has an elevation of 113 metres above sea level (a.s.l.) and was formed approximately 4500 years ago (Jacobs *et al* 1997: 196). West of the lake is the “Great Plain of Koukdjuak,” which was deglaciated between 7000-5000BP. The area consists of a sedimentary bedrock of fossiliferous limestone (Soper 1928:2) and the topography is described as a generally level glacial plain occasionally interrupted by a series of glacial landforms (e.g. eskers,

moraines). The plain is poorly drained and contains many shallow lakes and ponds (Stenton 1989: 90, 1991a: 20). Amadjuak Lake drains into Nettilling Lake via the Amadjuak River, and Nettilling drains into the Foxe Basin via the Koukdjuak River, which runs through the Great Plain (Jacobs *et al* 1997: 169). The eastern side of Amadjuak Lake is formed by the low margin of the Precambrian Highlands that comprise the east coast of Baffin Island. This area consists of the glaciated granite-gneiss bedrock of the Canadian Shield with a topography of low hills (Stenton 1989: 90, 1991a: 21).

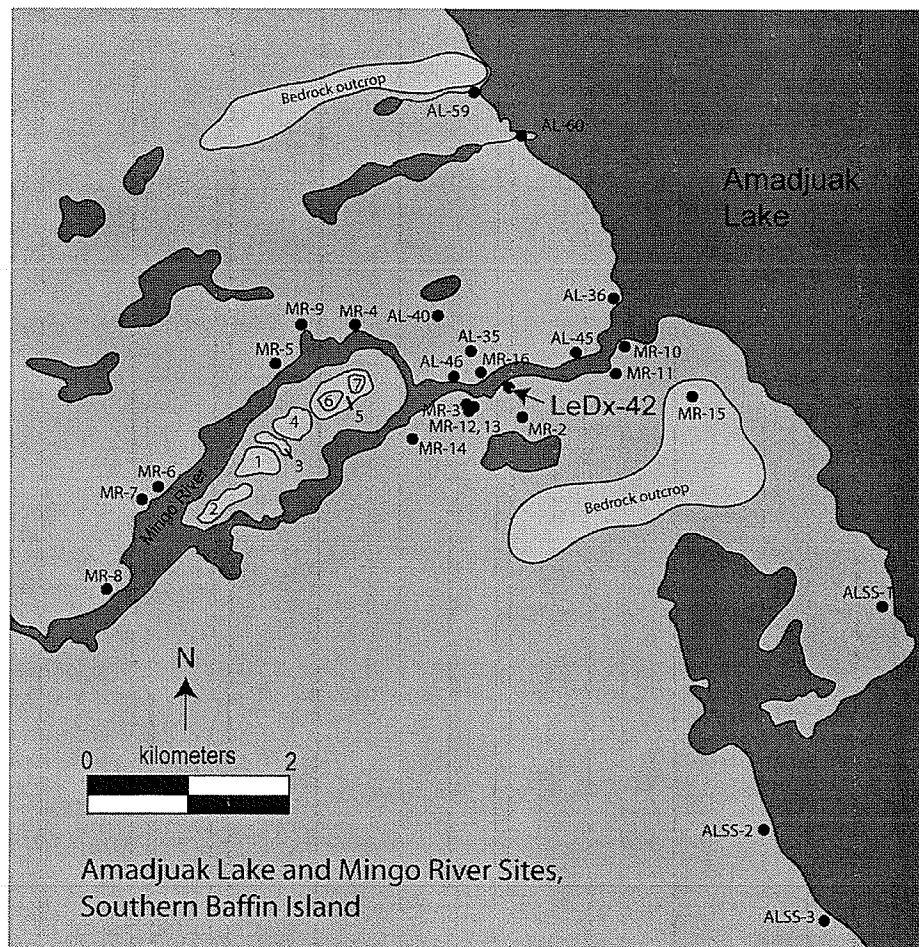


Figure 2.1 Location of the LeDx-42 site along the south shore of the Mingo River and southwest of Amadjuak Lake (Milne 2005).

Climate

Following Maxwell's (1980) division of the Canadian Arctic into five climatic regions, the study area falls within Sub-Region IVb, which encompasses the Gulf of Boothia, Foxe Basin, and western interior of southern Baffin Island. In this region mean annual temperatures range from -32°C to -28°C in January, and 5°C to 8°C in July. Total annual precipitation ranges from 175 to 250 millimetres with 40% to 50% of this falling as liquid precipitation (Maxwell 1980: Table 5). Additionally, the interior lowlands present an anomalous mesoscale climate with warmer summer conditions than the rest of the island (Jacobs and Grondin 1988). Part of the reason for this relative warmth is the area's low elevation and placement 100 km inland from the seasonally ice covered waters of the Foxe Basin (Jacobs and Grondin 1988: 214). However, the increased warmth is primarily due to the large amounts of solar heat absorbed and contained in Amadjuak and Nettilling Lakes (Jacobs and Grondin 1988: 215). This heat helps to regulate summer temperatures, which are approximately 2°C higher than the regional average. For example, the average July temperature at Burwash Bay between 1985 and 1986 recorded by Jacobs and Grondin (1988: 213) was between 8.5°C and 9.5°C . These temperatures are markedly different than those observed by Maxwell (1980). Overall, summers in the region are warm but short with dense clouds of mosquitoes while winters are intense, windy, and cold with continuous snow cover (Soper 1926, 1928).

Paleoclimatic data collected by Jacobs *et al* (1985: 59) for southern Baffin Island indicate that climatic conditions on the island often fluctuated between periods of relative warmth and cold. At 4500 BP the climate was warm and wet, but at 3000 BP these conditions shifted and became somewhat cooler and drier. Once again at 2700 BP

temperatures rose. It should be noted that this warming trend does not match climatic conditions observed in the rest of the eastern Arctic. Maxwell (1985: 34) notes that the period around 500 BC is marked by cold peak, which may have been reached a century earlier and persisted until 100 BC. The remaining period between 1800 BP and the end of the Palaeo-Eskimo culture is marked by rapid climatic fluctuations between cold from 1800-1500 BP to 1200-1100 BP, and relative warmth at 1400-1300 BP and 1000-800BP (Jacobs *et al* 1985:159).

Resources

Flora

The region's vegetation falls within the Low Arctic bioclimatic zone (Jacobs 1988: 75) and is characterized by the presence of various dwarf shrubs, grass-like herbs, grasses, sedges, rushes, mosses, lichens, and heath. The presence of these plants on the landscape is regulated by various microclimatic and topographic conditions (Jacobs 1988: 79).

Fauna

Caribou are the most important faunal resource in the Large Lakes District. These animals occupy an area extending from Amadjuak Lake northward beyond Nettilling Lake during the spring and summer months. Caribou are an economically valuable resource for hunters. In addition to providing sustenance, their bones and antlers provide valuable raw materials for tools and weapons, and their skins can be made into clothing (Stenton 1989: 56, 1991a: 18). Not surprisingly, caribou were an essential resource to all

occupants of the island. Ethnographic accounts (Boas 1964; Bilby 1923; Neatby 1977) and archaeological data from the Thule (Stenton 1989, 1991a), and Palaeo-Eskimo periods (Milne 2005a, Milne *et al* 2008a/b) reveal that throughout the human occupation of the island, people were travelling long distances from the coast to the interior to hunt caribou.

Additional fauna present in the area, as noted by Milne (2005a) in her 2004 field investigations of LeDx-42, include foxes, wolves, and a small number of bird species including red-throated loons, terns, gulls, ravens, and a variety of ducks.

Lithic Raw Material

Lithic raw materials are plentiful in the interior. Stenton (1991b: 11) and Milne (2005) have both observed profuse amounts of naturally occurring nodular chert littering the shorelines of Amadjuak Lake (see Figure. 2.2). This abundance should not be surprising considering the name of the lake. Amadjuak is an English corruption of the Inuktitut word Amaaq or Angmaaq, which means chert, and loosely translated Amadjuak Lake means “the place chert comes from” (Stenton and Park 1998: 25).

Lithic resources are scarce in the coastal regions of Baffin Island (Maxwell 1973: 10). Therefore, the interior was an important place for the Palaeo-Eskimo to procure toolstone (Milne 2003, 2005a/b, 2008, Milne and Donnelly 2004). In fact, Milne (2003, 2005a/b, 2008; Milne and Donnelly 2004) has argued that Palaeo-Eskimos were consistently travelling inland during the warm season to procure toolstone throughout the cultural continuum.



Figure 2.2 Picture of naturally occurring chert found near the shore of Mingo River taken in 2004 by Milne.

Site Area and Excavation Procedures

The Mingo River flows eastward from Mingo Lake, a smaller lake located southwest of Amadjuak, and drains into Amadjuak. LeDx-42 is located on a large bedrock outcrop that projects into the river on its south shore (see Figure 2.1; Milne 2005a: 9). The site was first discovered and tested by Milne in 2004. It is a multi-component Palaeo-Eskimo occupation and has produced six radiocarbon dates from the early Pre-Dorset, Transitional, and late Dorset periods (see Table 2.1). This is the first site on southern Baffin Island that contains occupations from all three Palaeo-Eskimo periods, and, perhaps most interestingly, it contains the first inland Transitional period occupations presently known in Nunavut.

Milne (2005a) noted an extensive surface scatter throughout the site including lithic debitage and formal tools. Many of these areas were selected for further sub-

surface investigation in order to determine the extent and nature of the occupation (Milne 2005a: 15). The majority of the sub-surface investigations were centered around a 20 × 20 metre² baseline through the central portion of the site. However, two one metre² units were excavated just north of the central baseline's most northern extent, and a second 6 × 2 metre excavation grid was established 11 metres north of the central grid. Additionally, 14 random test units were investigated along the site's most northern margin (see Figure 2.3). Overall, a total of 31.75 metres² were excavated to a sterile subsurface and the soil was screened through 1/4" and 1/8" hardware cloth (Milne 2005a: 15).

Table 2.1 Radiocarbon dates from LeDx-42 (Milne et al 2008a)

Sample Number	Measured ¹⁴ C Age	Conventional Age	Calibrated Date (2 σ)	Affiliation
Beta – 218087	3380 ± 40	3480 ± 40	3850 – 3640	Pre-Dorset
Beta – 208148	2340 ± 40	2450 ± 40	2730 – 2350	Transitional
Beta – 208149	2350 ± 40	2460 ± 40	2730 – 2360	Transitional
Beta – 218086	2210 ± 40	2320 ± 40	2360 – 2320	Transitional
Beta – 208157	1220 ± 40	1330 ± 40	1300 – 1180	Dorset
Beta – 218088	1290 ± 40	1380 ± 40	1350 – 1240	Dorset

The investigated units were extremely productive and yielded a large artifact assemblage. Organic preservation is exceptional at LeDx-42. In addition to the many caribou remains recovered, bone needle fragments, a harpoon perform with a clearly gouged hole, and a harpoon fragment with two drilled holes were found (Milne *et al*

2008a: 10). The lithic assemblage contains 29,648 flakes, and 87 informal and formal tools (Milne *et al* 2008a: 10, 2008: 17) including burins, burin spalls, microblades, core fragments, bifaces, and scrapers (Milne 2005a: 15). All of the artifacts are diagnostic of Pre-Dorset culture except for the gouged harpoon preform and a burin-like-tool, which are both characteristic of the Dorset culture (Milne *et al* 2008a: 10).

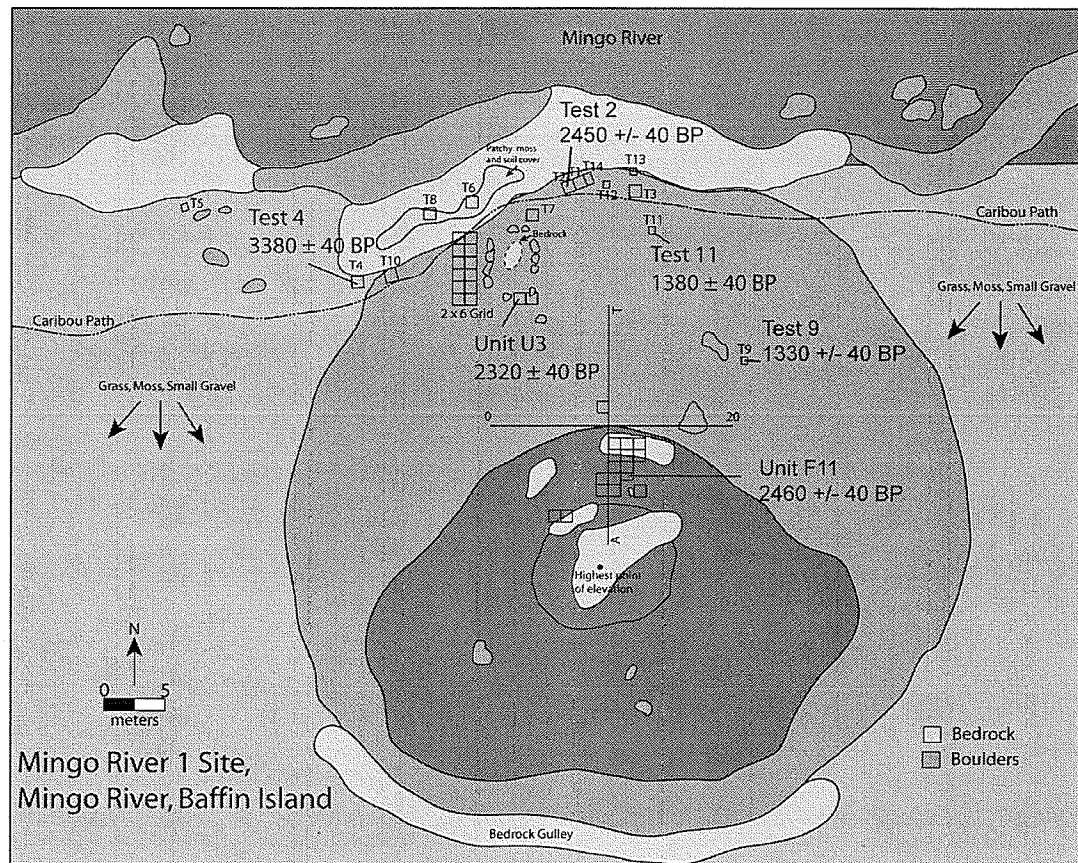


Figure 2.3 Site map of LeDx-42, Mingo Lake, Baffin Island (Milne 2005).

The extensive artifact assemblage present at LeDx-42 confirms its importance to the Palaeo-Eskimos and suggests the site was intensively reoccupied throughout the cultural continuum. The massive debitage assemblage indicates that tool manufacture

was a central activity at the site, but the presence of a diverse formal tool assemblage implies many other domestic activities were also taking place. Overall, this generalized artifact assemblage suggests that LeDx-42 was used as a long-term occupation site.

Preliminary Interpretations

While work continues at LeDx-42, Milne (2005a, 2008; Milne *et al* 2008a) has made some preliminary interpretations based on the material collected in 2004. The large quantities of lithic debitage present at LeDx-42 indicate that the locally available lithic resources available in the region were being extensively exploited. Compared to the debitage, there are relatively few formal tools present, and this results in a high flake:tool ratio. This ratio is used to measure the extent to which lost tool utility was being replenished through tool production and maintenance at a site (see Ricklis and Cox 1993: 450). Utility is lost when a tool is removed from the technological system, either through exhaustion, breakage, or loss, and is not replaced through the production of a new implement. In these instances, ratios will be low since new tools are not being worked and therefore, debitage is not being produced. Conversely, when new tools are being manufactured, particularly bifaces, much higher frequencies of debitage are produced thus resulting in notably higher ratios.

The flake:tool ratio at LeDx-42 is simply massive at 341:1 (29,648 flakes/87 tools) (Milne *et al* 2008a: 10). For perspective, the flake:tool ratio at the Mosquito Ridge (MaDv-11) site, an inland Palaeo-Eskimo site located near the Great Plain of Koukdjuak, is 40:1. This is considered high and is associated with core, biface, and blank production behaviours which produce large amounts of lithic debitage and leave very few tools

behind (because they were carried away with the toolmaker) (Milne and Donnelly 2004: 104). In comparison, the significantly higher ratio at LeDx-42 reveals the importance and extent of lithic reduction at the site. This ratio is notably higher than Mosquito Ridge given LeDx-42 was repeatedly occupied over many centuries. Consequently, this palimpsest of tool production activities has yielded a much larger lithic assemblage than would be expected from a single occupation site.

The primary activity at LeDx-42 was lithic procurement and tool manufacture to replace broken or exhausted tools (Milne 2005a: 18; Milne *et al* 2008a: 10). Indeed, the dominance of early and middle stage flake reduction indicates that tools were not being finished to completion on-site. Rather, toolmakers likely made preforms and blanks which would easily be transported away from the site and completed elsewhere (Milne *et al* 2008a).

The faunal assemblage at LeDx-42 contains over 1400 specimens, 99% of which are caribou. Modifications to these bones include fractures, spiral fractures, and splitting. All of these suggest intensive marrow extraction. Additionally, element representations indicate that these animals were being hunted and processed near the site (Milne *et al* 2008a: 10). Paired with the many hunting blinds, stone cairns, and meat caches near the site, it is apparent that caribou hunting was an important part of the Palaeo-Eskimo inland adaptation (Milne 2005a: 17).

Contrary to the assumed harshness of the Arctic, the interior of southern Baffin Island provided an inland oasis for its occupants with its elevated summer temperatures, abundant subsistence resources, and unrestricted access to lithic raw materials during the

warm season. Indeed the area appears to have been so inviting that the Palaeo-Eskimo repeatedly returned throughout their millennia long occupation of the Arctic.

Chapter 3

Palaeo-Eskimo Archaeology and Raw Material Selection

This chapter begins with a brief overview of the Pre-Dorset-Dorset Transition. Palaeo-Eskimo culture change and the role of lithic raw material selection are then examined. Finally, patterns of raw material procurement and selection as they pertain to the technological and social organization of Palaeo-Eskimo culture are discussed.

The Pre-Dorset-Dorset Transition

The first inhabitants of the Arctic are known archaeologically as the Palaeo-Eskimos. In the Canadian Low Arctic, Palaeo-Eskimo culture has been further subdivided by archaeologists to include the Pre-Dorset (4500-2800 BP) and Dorset (2500-1000 BP) cultures (Helmer 1994: 18). The temporal gap between these cultures represents the Transitional period (2800-2500 BP); a period of a few centuries in which archaeologists believe that a cultural change occurred between Pre-Dorset and Dorset based on the appearance (e.g. an extensive ground slate industry, rectangular soapstone vessels, bone sled shoes, snow knives, and ice creepers) and disappearance (e.g. bow and arrow, and bow-drill technology) of many cultural traits (Maxwell 1984: 363-4, 1985: 123).

At the center of this debate is the question of cultural continuity (e.g. Helmer 1994, LeBlanc 1994; Maxwell 1973; 1985; Meldgaard 1962, Nagy 1994, Taylor 1968). Presently there are three theories that attempt to account for Palaeo-Eskimo culture change: (1) it occurred as a result of gradual internal innovation over time; (2) drastic climate change forced Palaeo-Eskimo populations to develop radically different lifeways; and (3) the Palaeo-Eskimos were entirely replaced by a foreign population new to the eastern Arctic (Maxwell 1997: 205). While the majority of archaeologists believe that there was cultural continuity between Pre-Dorset and Dorset, the nature and catalyst of this change remains hotly contested (see Murray 1999; Nagy 1994).

Excavations by Collins (1956, 1957) at the T1 site on Southampton Island unearthed what he believed to be a new phase of the Dorset Culture. This new phase was called “proto-Dorset” or “pre-Dorset” and referred to those cultures antecedent to Dorset (Maxwell 1973: 296). Taylor (1968: 89) was the first to argue in favour of direct cultural continuity between Pre-Dorset and Dorset, thus suggesting an *in situ* development of Dorset in the eastern Arctic. Taylor (1968: 89) based his conclusions on data gathered from his excavations at the Arnapiik and Tyara sites located in Nunavik where he found that there was a large number of lithic and organic artifacts from the Dorset Tyara site that were either duplicated or derived from artifacts recovered from the Pre-Dorset Arnapiik site. Studies by Nagy (1997, 2000) in Nunavik, and Maxwell (1973) in the Lake Harbour District of Baffin Island also make arguments in support of an *in situ* development.

Proponents for the *in situ* development of Dorset have further suggested that Palaeo-Eskimo culture changed in response to climatic cooling which occurred around

600 and 500 BC (McGhee 1996: 120; Maxwell 1985: 122). In order to cope with a colder climate, which expanded the extent and duration of annual sea ice, Palaeo-Eskimos appear to have significantly changed their existing lifeways. A focus on sea ice hunting and a primarily marine economy emerged with Dorset and replaced the dualistic terrestrial-marine economy relied upon by Pre-Dorset. This shift likely occurred because marine resources were considered more stable and reliable than terrestrial resources (Maxwell 1985: 122-3; Murray 1999: 474-475; McGhee 1996: 120; Fitzhugh 1976: 141).

The “core area” has been a region of great interest to archaeologists regarding the emergence of the Dorset culture. The core is a geographic region roughly 1,000 km in diameter and includes the coastal regions of the Fury and the Hecla Strait, Hudson Bay, and Hudson Strait (McGhee 1976: 15). It is an area of diverse, productive, and predictable resources that is believed to have been continuously occupied throughout the Palaeo-Eskimo cultural continuum (McGhee 1976; Fitzhugh 1997: 397). The regions surrounding the core are called “fringe areas.” McGhee (1976: 16) has identified six fringe occupation areas: the High Arctic; the Central Arctic coast, the western Barren Grounds, the west coast of the Hudson Bay, the eastern Hudson Bay coast and islands, and Newfoundland and Labrador. These areas are distinguished from the core by discontinuous human occupations throughout the Palaeo-Eskimo continuum (McGhee 1976: 15). The occupation of these areas was influenced by climatic conditions which dictated the availability of important subsistence resources (Fitzhugh 1976: 141; 1997: 391). In the core, resources were more abundant and predictable than those in the fringe areas, and thus more reliable during periods of climatic instability.

Fitzhugh (1976: 146) attributes the absence of early Dorset in southern Hudson Bay to sea ice conditions incompatible for breathing hole sealing, and a probable reduction in caribou populations due to colder weather. He suggests that the Palaeo-Eskimos more than likely abandoned the area for the more productive northern Hudson Bay area (Fitzhugh 1976: 147). On southwestern Victoria Island, Savelle and Dyke (2002) found that Pre-Dorset continuously occupied the area from their initial arrival 4500 years ago until around 4000 BP. At 3800 BP and again at 3200 BP Palaeo-Eskimo populations declined abruptly, and by 2800-2600 BP the population had disappeared entirely (Savelle and Dyke 2002: 518). One explanation for the decline and ultimate disappearance of the Palaeo-Eskimos on southwestern Victoria Island is the gradual cooling trend that occurred in the area and became especially pronounced after 3500 BP (Savelle and Dyke 2002: 519). Once again, a gradual change in temperature may have compromised the local resource base upon which the Palaeo-Eskimos depended and eventually forced them to abandon the area.

Conversely, the stable environment of the core area allowed the Palaeo-Eskimos who lived there to survive and thrive in the extreme Arctic landscape over a 3500 year period. Additionally, by absorbing migratory fringe populations, the core fostered an environment where Palaeo-Eskimo populations could gather and share new and old ideologies. Thus, the core provided a likely location for the Dorset culture to develop and later spread out across the Arctic as a homogenous cultural unit (McGhee 1978: 51; Maxwell 1985: 82)

Not all archaeologists rely on the core/fringe model to explain culture change in the Arctic. Maxwell (1985: 51) suggests that the core area concept may simply be an

artifact of limited Arctic exploration at the time of its development. Indeed, some archaeologists believe that the change from Pre-Dorset to Dorset occurred throughout the eastern Arctic instead of in a single localized area (Maxwell 1985: 121-128; Sutherland 1991, 1996; Cox 1978; Schledermann 1990). Instead of focusing on large scale climatic shifts to explain culture change, Sutherland (1991) suggests that archaeologists should focus their attention on local populations and their adaptations to changing environments. For example, on Ellesmere Island sea ice conditions were unfavourable for hunting throughout the Palaeo-Eskimo period. Instead of abandoning the area to follow a typical terrestrial-marine Palaeo-Eskimo economy, the inhabitants of the area relied on the local muskoxen population and developed their own unique terrestrial economy (Sutherland 1996). Localized climatic conditions and changing social and political behaviours make it virtually impossible for archaeologists to explain the emergence of an entire culture, and so it is more advisable to study many small localized populations and eventually use these accumulated data to explain large scale culture change (Sutherland 1991: 146).

Sutherland (1996) believes that the Palaeo-Eskimo occupation on northern Ellesmere Island was continuous. While artifact assemblages were varied in the types of raw materials and technological attributes used throughout the continuum, assemblages from the same temporal periods were similar (Sutherland 1996: 279). The earliest Independence I (an early Palaeo-Eskimo culture adapted to the High Arctic) assemblages contain large crude bifaces with tapered stems, edge-ground adze blades, finely worked edge-serrated weapon points, notch-hafted burins, burins spalls, microblades, and small flared endscrapers, while later Independence I assemblages are nearly the same except for an absence of adze blades (Sutherland 1996: 279). Independence II (a High Arctic

Transitional culture) assemblages from the island are characterized by the presence of large flared endscrapers, “cloven hoofed” lance-heads, straight-stemmed bifaces, and bone needles with flat cross-sections (Sutherland 1996: 281). It is most likely that, once established in Independence I, technologies on Ellesmere Island gradually changed over time due to sporadic contact with distant Palaeo-Eskimo populations, and localized technological adaptations to the environment (Sutherland 1996: 286). An ongoing diffusion of Palaeo-Eskimo technological attributes throughout the Arctic can be used to explain the homogenous Dorset culture represented in the archaeological record rather than cultural replacement from a single area (Sutherland 1996: 286).

The final theory suggests discontinuity in the continuum; Dorset was a distinct cultural entity which replaced Pre-Dorset. Jorgen Meldgaard (1960: 75) once wrote that the early Dorset culture “smells of the forest.” He believed that the new cultural traits that emerged within the Dorset culture were, at the very least, strongly influenced by the Late Archaic and Early Woodland cultures living south of the coniferous belt (Meldgaard 1960: 75). This suggestion has gained little support from most researchers. In fact, in his study of Palaeo-Eskimo populations in Labrador, Harp (1963) found no traces of interaction between Dorset and southern Aboriginal cultures. Harp concluded that if there was no interaction in an area where the two groups’ territories were so close, it was unlikely that it occurred elsewhere.

While there may not have been a southern influence in the development of Dorset, some researchers have suggested discontinuity in the Palaeo-Eskimo cultural continuum. Ramsden and Tuck (2001), Gendron and Pinard (2000), and Derosiers and Gendron (2004) suggest cultural discontinuity between Pre-Dorset and Dorset based on marked

differences in the two culture's artifact styles. During the Dorset period bow drill, and bow and arrow technology disappear, while breathing-hole sealing gear and sleds appear. Additionally, open socket and sliced harpoon heads are replaced for closed socket forms, true spalled burins for burin-like-tools, and round and oval soapstone lamps for rectangular forms (Ramsden and Tuck 2001: 8). Instead these researchers believe that those sites classified as early Dorset mark the end of the Pre-Dorset culture, and middle Dorset the beginning of Dorset.

The question of culture change between Pre-Dorset and Dorset remains unresolved, simply because archaeologists have been unable to provide definitive evidence of continuity or discontinuity between the two groups. This is because reliable dates for most sites are unavailable, and the classification of sites is based principally on subjective criteria (i.e. the presence/absence of Pre-Dorset and/or Dorset traits), and intuition (Nagy 1994: 3).

Palaeo-Eskimo Culture Change and Raw Material Selection

Changing patterns of lithic raw material selection and use throughout the Palaeo-Eskimo continuum has been taken by some archaeologists as an indicator of culture change between Pre-Dorset and Dorset (e.g. Gramly 1978; Maxwell 1985; McGhee 1996; Schledermann 1990, 1996; Sutherland 1996; Nagy 1997, 2000). Generally, Pre-Dorset raw material selection tended to be less specific than Dorset who are interpreted as having been highly specific in their raw material choices.

On the coast of Labrador, high quality and locally available Ramah chert only became widely used during the middle Dorset period. Beforehand, the Pre-Dorset

depended on opaque cherts of lower quality. However, once in use, Ramah chert, paired with crystal quartz, were virtually the only types of raw materials used in the area (Gramly 1978: 37). On northern Ellesmere Island eleven types of chert and a single type of basalt are locally available. Early in the Independence I occupation of the island there was variability in the types of raw materials used for tool manufacture. However, during late Independence I, the use of a light grey chert begins to dominate artifact assemblages and continues to be almost exclusively used into the Independence II period (Sutherland 1996: 282).

Patterns of raw material selection also changed in the Lake Harbour District of southern Baffin Island. During the Pre-Dorset period, toolmakers relied almost completely on a locally available light tan chert. Seventy-five percent of the lithic artifacts excavated by Maxwell (1973: 300) were made from this material, while the remaining 24% of tools were made from crystal quartz. Over time, Maxwell (1973: 48) notes that crystal quartz became increasingly more popular in the region and suggests that it is possible to infer the relative age of a site based on the differential frequencies of specific raw materials. Indeed, throughout the Arctic, Dorset sites are defined by the increasing presence of green nephrite, crystal quartz, and other scarce lithic resources, and this suggests that the Dorset were becoming more selective in the types of raw materials used for tool manufacture (Maxwell 1985: 123; McGhee 1996: 140; Schledermann 1996: 98).

Nagy (1997, 2000) has gone even further to suggest that changes in Palaeo-Eskimo raw material selection were not only markers of social change, but also of social complexity. Relying on Binford's (1980) forager/collector model, Nagy likens Pre-

Dorset to foragers and Dorset to collectors. She believes that a group's knowledge of the land influenced how they exploited an area's resources (Nagy 2000: 143). Because Pre-Dorset were new to the land, they behaved like foragers. Not knowing what the land had to offer, they exploited resources opportunistically and in a non-specialized manner. Dorset, on the other hand, had lived on the land longer and, therefore, had accumulated enough environmental knowledge to practice more specialized resource exploitation strategies (Nagy 2000: 143-44). As expected in Nagy's (1997: 2000) Nunavik study area, the Pre-Dorset lithic assemblage is made almost entirely of locally available chert, but during the Transitional period, toolmakers started using other lithic materials and quartz became an important lithic raw material. Finally, during the Dorset period, chert accounted for only 50% of the lithic assemblage. The remaining tools were made from quartz and crystal quartz derived from nearby source areas, and an exotic quartzite, nephrite, and a few types of high quality chert were thought to be acquired through trade or long distance travel (Nagy 1997: 171, 2000: 146).

Raw Material Procurement

It is important for archaeologists to know where and how toolmakers were procuring raw materials because the different strategies used to acquire stone have different costs and benefits. These are measured by the amount of time and energy expended to acquire the desired material, and this ultimately influences how tools were made. These strategies include: exchange, direct procurement, and embedded procurement. When raw material is secured through trade, the costs of the transaction are established by an agreed upon value of the goods or services (Morrow and Jeffries 1989:

30). Within an *embedded* procurement strategy (Binford 1979), raw materials are captured incidentally during the execution of larger subsistence tasks, and it is “only when things have gone wrong, does one go out into the environment for the express and exclusive purpose of obtaining raw material for tools” (Binford 1979: 259). An example of embedded procurement among the Nunamuit Eskimo described by Binford (1979:259) illustrates this point:

A fishing party moves in to camp at Natvatrauk Lake. The days are very warm and fishing is slow, so some of the men may leave the others at the lake fishing while they visit a quarry on Nassaurak Mountain, 3.75 miles to the southeast. They gather some material there and take it up on top of the mountain to reduce it to transportable cores. While making the cores they watch over a vast area of the Anaktuvuk valley for game. If no game is sighted, they return to the fishing camp with the cores. If fishing remains poor, they return to the residential camp from which the party originated, carrying the cores.

In this model, raw material procurement is embedded within another activity, typically related to subsistence, and it is opportunistic in nature since it is pursued when the group’s original task does not pan out. Therefore, any costs that could be attached to the procurement of stone are eliminated because cost is always attached to the larger subsistence task. The cores that Binford describes were manufactured with little to no additional cost because they were carried home in lieu of the fish the hunters did not catch (Binford 1959: 259). To Binford (1979: 261) the presence of exotic stone within an assemblage did not mark a group’s preferential selection of stone; rather, it simply reflected the scale of a group’s mobility.

Conversely, some archaeologists believe the presence of exotic raw materials to be a result of *direct procurement*, where individuals or groups make special purpose trips to the source to acquire stone. Unlike embedded procurement, additional effort is

expended by individuals in the acquisition of stone, whether in the distance travelled to or from the source, the extraction/quarrying of stone, the transport of materials, or scheduling trips to the raw material source at the expense of carrying out other activities. This additional effort should be visible in the archaeological record since toolmakers will treat their tools with greater care when they have invested significantly more effort in procuring the required stone (Morrow and Jeffries 1989; Jeske 1989). For example, when a group employs an embedded strategy, stone is collected incidentally so exotic stones should be used in an identical manner to local stone as it serves no special purpose (Morrow and Jeffries 1989: 30). In contrast, if a group finds that local stone is inferior in quality for their needs, they will choose to invest more time and energy in search of better quality material. Therefore, archaeologists can expect to see different proportions of exotic and local stone in an assemblage, which, in turn, should be reflected in the kinds of tools found and their intensity of use (Morrow and Jeffries 1989: 30; Jeske 1989: 36; Andrefsky 1994a/b).

Lithic Source Areas

Archaeologists have long recognized the importance of ancient raw material source areas in raw material procurement. Almost 90 years ago, William Henry Holmes (1919) noted the importance of quarries when studying prehistoric trade and culture contact. We now know that the systematic study of prehistoric procurement sites can provide archaeologists with an array of information on the strategies and stages of reduction carried out at a quarry, the kinds of materials transported away, the rates of

quarry usage over time, the techniques used to extract stone, and an overall understanding of a group's larger technological and social organization (Bamforth 2006: 512).

Generally, the presence of exotic raw materials in an assemblage is accepted to be an indicator of group mobility or exchange. It is assumed that groups either acquire raw materials by direct procurement from the geological source, or through a trade network where goods were exchanged from group to group (Gramly 1980: 828, see also Boldurian 1991; Macdonald 1968; Wilmsen 1973; Meltzer 1989). Unfortunately, the presence of exotic stone in an assemblage only proves that the stone itself moved away from its original source, not how it moved (Webb 1974: 360). Exchange is difficult to empirically prove because the presence of stone could just as easily be the result of direct acquisition whereby stone was procured at the original geological source and then carried by toolmakers to a site, or stone could have been carried over a great distance by natural factors (e.g. glaciation) and procured directly at its secondary context (Meltzer 1984: 4; 1989:12-13). Because of these difficulties, the remainder of my discussion will focus on direct acquisition and mobility.

Unfortunately, the presence and proportion of raw materials is not a simple indicator of group mobility either. By employing three hypothetical simulations of hunter-gatherer stone procurement, Ingbar (1994) found that mobility was not even a major influence in the proportion of raw material types within a lithic assemblage. No matter how mobile a group may be, lithic raw material sources may not always be available. Source areas may simply not coincide with other group activities like the procurement of important subsistence resources (Torrence 1983). Alternatively, they may simply be seasonally restricted (see Wenzel and Shelley 2001; Tankersly 1995), or

may just be of too poor of quality to invest time and energy in collecting (Andrefsky 1994a/b). In response to these conditions, groups will choose how to organize themselves accordingly so they will not be without toolstone. These organizational patterns will ultimately influence the types of stone present in an artifact assemblage. For example, at the Hanson site, a Folsom lithic workshop in north western Wyoming, local materials were being reduced in a variety of ways, but the products of this manufacture (i.e. bifaces) are not present. In fact, the majority of formal tools are made from non-local and/or exotic stone (Ingbar 1994: 51). In this case, highly mobile Folsom groups were renewing their toolkits whenever they happened upon a raw material source. When this happened, individuals discarded their old tools and fashioned new ones from local stone.

A similar pattern is seen at the Mount Jasper lithic source in northern New Hampshire where glassy rhyolite with superior flaking quality is available. In a study of the source area, Gramly (1980) discovered an unexpected class of tools which he called *rejectamenta*. These tools consisted of finished implements that were heavily worn and/or recycled. There is little evidence that individuals camped out at Mount Jasper long enough to cause the heavy wear on the tools, and most of the rejectamenta tools were made from exotic stone. Once again, it is likely that individuals were rejecting their old tools in favour of freshly made tools from rhyolite (Gramly 1980: 826).

Archaeologists studying highly mobile cultures, like the Palaeo-Eskimos, should expect to see similar patterns of discard and retooling. The bulk of the debitage and informal tools will be from local sources and most of the formal tools will be made from exotic

stones, and most likely from the last few sources they visited by the toolmakers (Ingbar 1994: 52).

Mobile hunter-gatherers, like the Palaeo-Eskimos and those populations at the Hanson site and Mount Jasper, devised organizational strategies to ensure that they will always have enough toolstone for an effective and functional toolkit. Therefore, it is necessary for archaeologists to know where lithic source areas occur in their chosen region of study if they are to understand how and why individuals were exploiting them in the past.

Lithic Source Areas in the Arctic

While it has been generally accepted that differential patterns of raw material selection denote Palaeo-Eskimo culture change, only a few raw material sourcing studies have been done in the Arctic (e.g. Gramly 1978; Lazenby 1980; Jensen and Brinch Petersen 1998; Le Blanc 1991; Cook 1995), and of these, only four have moved past simple description of the source areas (Gramly 1978; Jensen and Brinch Petersen 1998; Lazenby 1980; Le Blanc 1991). Gramly (1978) and Lazenby (1980) have worked to describe lithic source areas in the Ramah and Mugford areas of Labrador, and Gramly (1978) has further sought to understand why Ramah chert was more commonly selected over other locally available lithic materials of equal quality and abundance. In Ramah Bay, chert outcrops are abundant, easily accessible, and of high quality, whereas the three types of chert available in the Mugford area (Cod Island, Kaumajet, and Kaumajet Black chert) are either of poor quality or perched high atop a talus slope and difficult to access (Gramly 1978). It has been well established that throughout history Ramah chert was not

only an important lithic resource in Labrador, but it was an equally important trade good that was exchanged throughout the eastern Arctic (Gramly 1979; Loring 2002). Gramly (1978: 46) suggests that Ramah chert was simply the most accessible: “a large volume of chert could be won without too much digging or clearing, and in comparison to other lithic sources it was ‘cheap.’”

Jensen and Brinch Petersen (1998) have studied killiaq, the dominant raw material used during the Saqqaq period (a regional variant of early Palaeo-Eskimo culture found in Greenland) in central West Greenland. Two killiaq extraction sites are known in the area; the first at Qaarsut on the northern shore of the Nuussuaq Peninsula, and the second on the island of Angissat in the southern part of Disko Bay. Using visual characterization, the authors sought to understand the cultural distribution of killiaq throughout Greenland. Large coastal settlements and the intensity of blade production at Qaarsut led the authors to believe that killiaq from this area was harvested for “export purposes” (Jensen and Brinch Petersen 1998: 145). On the other hand, Palaeo-Eskimo structures in Angissat are rare and tool production was much less intense. Therefore, the authors believe that the primary use of Angissat killiaq was local and its procurement was embedded (Jensen and Brinch Petersen 1998: 145). In Greenland, killiaq was carried as far as 600 km, but unfortunately it is unknown whether its movement was the result of exchange or direct procurement.

Whether as large bedrock outcrops or nodules, lithic source areas are most often spatially fixed. Many of these areas have been exploited for hundreds or thousands of years, as is evidenced by the staggering amounts of cultural remains found at quarry sites. However, this is not the case with clinker sources found on the Cape Bathurst Peninsula

(CBP). CBP is home to the Smoking Hills, which contain features of naturally burning sediments called *bocannes*. This burning process involves the spontaneous combustion of Smoking Hills formation shale, which creates a fused clinker that was used by prehistoric inhabitants of the area to manufacture a wide range of tools (Le Blanc 1993: 6). Bocanne quarries are dynamic; while some are exhausted or destroyed (e.g. ice scour and fluvial/marine erosion) others are forming (Le Blanc 1991: 271; 1993: 54). Therefore, groups had to adjust their procurement strategies with the constantly changing source areas (Le Blanc 1991: 272). It has been extremely difficult to locate prehistoric quarry sites on CBP, but there is no doubt that clinker was the most commonly used raw material in the area. There is evidence that clinker was transported as far as 160 km to the west and 280 km southwest of CBP, and Le Blanc (1991) believes that this distribution of clinker was the result of direct procurement and transport, but does not dismiss the possibility of exchange.

Raw Material Selection

Many cultures preferentially selected specific types of raw materials for tool manufacture. Perhaps the best known example of preferential selection is the Paleo-Indians who consistently selected only the highest quality cryptocrystalline cherts and often travelled great distances up to 100-350 km to procure it (e.g. Ellis 1989: 142; Goodyear 1989; MacDonald 1998, 1999). However, a number of other examples exist including Late Archaic and Early Woodland groups throughout the northeastern and midwestern United States who acquired blue hornstone chert through exchange and used it for the manufacture of burial goods known as Turkey Tail points (Didier 1967).

Similarly, during the Late Woodland, toolmakers throughout the Mississippi valley chose dense, tough Illinois Mill Creek chert for the manufacture of bifacially flaked hoes for farming (Morrow and Jeffries 1989). To these groups, preferential selection of stone was likely a means to fulfil the technological and social needs of their culture (see MacDonald 1998, 1999). To archaeologists it is a means to distinguish different cultures and understand their respective patterns of behaviour. The following section examines raw material selection strategies as they pertain to the social and technological organization of hunter-gatherer toolmakers. The intent is to understand why individuals select specific raw materials and how these choices influence the types of tools they produce. Drawing from this information, I will examine Palaeo-Eskimo raw material selection strategies in an effort to understand their technological organization.

Technological/Mechanical Selection

Chipped or flaked stone artifacts are best produced from raw materials that fracture in a predictable manner. These stones tend to be brittle, homogeneous, and isotropic (Andrefsky 1998: 25). Glassy or fine-grained volcanites like obsidian and cryptocrystalline (or microcrystalline) silicates, like chert, are good examples of raw materials used to produce flaked stone tools (Andrefsky 1998: 23; Odell 2004: 21). However, while these materials possess the ideal qualities for flaking, their mechanical efficiencies vary according to the task at hand (Beck and Jones 1990: 284).

Obsidian was largely ignored by the Paleo-Indians (Goodyear 1989: 7). While obsidian is perhaps one of the best raw materials for tool manufacture and produces an extremely sharp edge (Beck and Jones 1990: 284), it is not very durable and is unreliable

for scraping, and boring tasks. Chert, on the other hand, is much tougher (Goodyear 1989: 7; Beck and Jones 1990: 284) and can be fashioned into a wider range of tool types with greater functional longevity. The Paleo-Indians were the first populations to inhabit the North American continent south of the ice sheets approximately 12,000 years ago. They were highly mobile and quickly adapted to their new and challenging environment. This mobility may have occasionally limited a group's access to raw materials since stone sources do not always correspond with other resources being exploited and/or activities being undertaken (Kelly 1988: 718; Beck and Jones 1990: 255). As a result, groups had to conserve stone and maximize the use-life of their tools. Goodyear (1989: 3) has stressed the importance of a portable and flexible toolkit for Paleo-Indians. Goodyear (1989: 3) has defined flexibility as "[the creation of] tools with lifespans long enough to be used on a number of occasions if necessary." Thus, the creation of a standardized technology, where the toolmaker knows the intended product of manufacture and is aware of the specific procedures necessary to create and re-create the desired product (Arnold 1987: 232), is necessary. The Paleo-Indian toolkit consisted of a number of multi-purpose and multi-function tools that could easily be altered into a desired tool, easily re-sharpened for multiple uses, and/or recycled into a new tool (Parry and Kelly 1987: 298).

Social Selection

Patterns of raw material selection may also be influenced by a group's social organization. Ellis (1989) suggests that the strong preference for certain raw materials in Paleo-Indian assemblages "[served] as a stylistic indicator of homogeneity in identity to

[a] group's members" (Ellis 1989: 156). He further suggests that the homogenous selection of certain raw materials served to de-emphasize the social differences within a group and facilitated the exchange of ideas (Ellis 1989: 156). The exchange of raw materials between similar groups may also have served to create and maintain certain social relations at the inter-group level. Hayden (1982: 114-19) suggests that Paleo-Indians exchanged high quality raw materials in order to create social relations. These ties could then be called upon in times of resource stress or failure.

Population densities in the New World during the Paleo-Indian period were extremely low. In order to maintain the biological viability of the Palaeo-Indian culture, groups likely emphasized social unity in order to maintain social ties and find mates. The presence of exotic stones in most Paleo-Indian lithic assemblages is likely a reflection of their high mobility (MacDonald 1998: 227). MacDonald (1998) has suggested that the great frequency and extent of Palaeo-Indian mobility was not only the result of their subsistence patterns, but also of their need to find mates. MacDonald (1999: 149) was able to discern Folsom mobility by linking artifacts from northern and central Plains sites to their original geological sources. It was during forays to acquire stone that individuals encountered other social groups; and it was in the exchange of these raw materials that social relationships were formed and legitimized (MacDonald 1999: 144).

At the Puntutkarpa Rockshelter habitation site located in the Western Desert of Australia small amounts of exotic chert were used for tool manufacture even though superior quality stone was locally available. Gould and Saggers (1985: 118) predict that this was done to mitigate stresses imposed by drought through the development of social networks. Western Desert Aborigines often made special purpose trips to lithic sources,

which were commonly near sacred sites (Gould and Saggers 1985: 120). On many occasions, visitation to these sacred sites was the primary purpose for the journey. Once they reached the site, the travelling group would meet with the members of the patrilineage who controlled the land, novices would be introduced to the myths associated with the landscape, betrothals would be organized, and, in general, new social alliances would be created while old ones were maintained. These acts secured the visitors future use of the land and its resources in times of stress (Gould and Saggers 1985: 122).

Palaeo-Eskimo Raw Material Selection

Much like the Paleo-Indian toolkit, the Palaeo-Eskimos expended additional effort in the manufacture of their toolkit to ensure that tools were versatile, long-lived, easily maintained, and recycled (Andrefsky 1998: 213). Microblades shaped from prepared cores were advantageous because they predictably produced small multi-functional blades with extremely sharp edges (Maxwell 1985: 90). The Palaeo-Eskimos also relied on bifacial technology. Bifaces are an efficient technology because they can be used as both cores and tools. These tools are durable, easily sharpened, have long use-lives, and have the potential to be recycled into other tools (Kelly 1988: 718). The flakes driven from bifacial cores are extremely sharp and versatile. The core itself is easily transported and allows the user a certain amount of preparedness for tasks that may arise in their daily life (Parry and Kelly 1987: 298; Kelly 1988: 718). Simply stated, formalized technology is an adaptive choice for mobile hunter-gatherers because it permits a fixed

set of tool needs to be filled with a smaller number of tools made from a smaller weight of raw material (Parry and Kelly 1987: 298).

Some Arctic archaeologists believe that Palaeo-Eskimos predictably chose specific exotic raw materials over other locally available stones for reasons beyond simple technological proficiency (Loring 2002: 164; Maxwell 1973: 300; McGhee 1996: 136-40). As Loring (2002: 164) writes: "Indubitably, chert [and other lithic raw material] varieties were used to signal some form of social identity." McGhee (1996) has noted that the Dorset were extremely particular about the raw materials they used to manufacture certain tools. The necessity of using specific materials (e.g. jade, jadeite, and nephrite from the Canadian Shield, copper from the central Arctic, and iron from north western Greenland) resulted in the development of extensive trade networks throughout the central and eastern Arctic (McGhee 1996: 138-40).

Odess (1998) took the presence of visually distinctive stone types, Ramah Chert from Labrador and Southampton Island banded chert, as indicators of Palaeo-Eskimo interaction in the Frobisher Bay District. In studying lithic assemblages from this region, Odess (1998: 430) believes that the presence of these distinct raw materials is "indicative of an effort on the part of these people to reach out across hundreds of kilometres of apparently unpopulated territory to forge social ties with groups...so that they could secure access to the fine and good things that interaction brings."

In the Arctic, the Palaeo-Eskimos very likely practiced similar mobility patterns as the Folsom Paleo-Indians (Milne 2008) who were likely travelling between 160-500 km to procure stone, and create social and reproductive networks (MacDonald 1999: 152). However, the Palaeo-Eskimos also faced seasonal (e.g. snow) and geologic

restrictions when procuring their toolstone. So, if Folsom were travelling on average 330 km in an estimated population density of .001 persons/km² (MacDonald 1999: 152), the Palaeo-Eskimos were probably traveling even further to fulfil their social needs as population densities in the eastern Arctic were likely even lower (Milne 2008: 11).

On southern Baffin Island, the Palaeo-Eskimos seasonally traveled between the coastal and inland regions (Milne 2003). During the winter, they relied on marine resources to fulfil their subsistence needs and during the spring, summer, and early fall, they moved to the interior to exploit terrestrial resources (Milne 2003, 2005a/b, 2008; Milne and Donnelly 2004). The Palaeo-Eskimos also relied on the abundant supply of lithic raw materials found in the interior of the island (Milne 2003, 2005a/b, 2008; Milne and Donnelly 2004), because stone sources are more scarce in island's coastal regions (Maxwell 1973: 10). Milne (2003, 2005a/b, 2008; Milne and Donnelly 2004) has further established that stone procurement was structured into the Palaeo-Eskimos' seasonal round, and that sites in the interior appear to have been habitually reoccupied for millennia.

The abundance of lithic raw materials made the interior region an ideal location to teach novices to flintknape (Milne 2005b: 338; 2008: 13). Flintknapping not only taught novices a technical skill, but it also taught them important social values (Milne 2005b: 337; 2008: 19). Milne (2008) believes that the Palaeo-Landscape was likely defined by specific travel routes (e.g. hunting, camping, stone extraction locations). Inhabitants may have shared local stories and expectations about specific behaviours, norms and values associated with the location. Annual treks to the interior may have served an important purpose in the enculturation of novices; the journey taught them about their cultural

landscape. The central location of the interior made it an ideal place for individuals to procure stone and socialize. It also would have provided novices, both male and female, the opportunity to interact and find potential mates (Milne 2008: 20).

Patterns of raw material selection and use can reveal a great deal about a culture, but before archaeologists can learn anything from the types of raw materials present on a site it is first necessary to learn about the available lithic source areas in a region and how they were being exploited. The ways in which a group chooses to procure raw materials is influenced by a number of external causal factors (discussed in the next chapter) and the group's social organization. Therefore, if archaeologists can determine the causal factors that influence procurement and know the types of raw materials being used and how they were being exploited, they can learn why certain raw materials were being exploited and gain valuable insight into the group's larger social organization.

Chapter 4

The Organization of Technology

This chapter begins with a brief overview of the organization of technology. The technological strategies employed by toolmakers to produce adaptive technologies (i.e. curated, expedient, and bipolar reduction) are reviewed, and are followed by a discussion of the causal factors which influence their selection (i.e. mobility, time scheduling, and raw material availability). Finally, using the information presented in this chapter, three working hypotheses and their related test expectations are presented to assess Palaeo-Eskimo patterns of raw material selection and use at the LeDx-42 site.

The Organization of Technology

For decades archaeologists have studied the organization of technology (i.e. lithic, ceramic, organic, and metal) to learn about past populations (e.g. Andrefsky 1994; Jeske 1992; Kelly 1988; Nelson 1991; Parry and Kelly 1987; Shott 1986, 1989; Torrence 1983, 1989a). Binford's seminal studies of the Nunamuit (1977, 1978, 1979, 1980) and Alyawara (1984, 1986) are credited with the development of this approach. His studies sought to understand how technology was integrated within existing cultural systems, as well as determining site formation processes. By studying living hunter-gatherers,

Binford was able to observe the technological strategies employed to make, use, maintain, modify and discard tools, and the specific circumstances that influenced their production. From his observations, he was able to correlate specific technological strategies (i.e. curated vs. expedient) with associated patterns of behaviour.

Archaeologists view technology as an adaptive strategy used by groups to cope with their social and physical environments (Koldehoff 1987; Nelson 1991; Kelly 1988; Torrence 1989). Therefore, technology must be dynamic in order to deal with the changing circumstances that a culture faces in their day-to-day lives (Koldehoff 1987; Nelson 1991). Unique technological strategies are devised as toolmakers react to their environment, and, consequently, use of these strategies will change according to the group's immediate and anticipated needs. Depending on specific causal factors (e.g. the availability of stone, mobility and settlement patterns, activity scheduling), toolmakers will pick a technological strategy that best fits a given situation. Technology should not simply be seen as objects used by humans to cope with external forces; rather, it should be viewed as a composite of human behaviours that are drawn upon to cope with the environment (Koldehoff 1987: 152; Kelly 1988: 717; Nelson 1991: 59, 62). Therefore, these tools, once uncovered by archaeologists, can be used to make direct correlations to the people who once used them (Nelson 1991: 62).

Many levels of analytical questioning are present in the great body of literature on the organization of technology. This literature has been synthesized by Nelson (1991) and organized into a hierarchical framework to facilitate understanding and discussion (see Figure 4.1). Nelson's (1991: 57) model focuses on the "the selection and integration of strategies for making, using, transporting, and discarding tools and the materials

needed for their manufacture and maintenance” (Nelson 1991: 57). These strategies are influenced by environmental, social, and economic variables. While each level of analysis presented in Nelson’s (1991: 57, 59) model is important in understanding a group’s overall technological organization, she acknowledges that most studies will emphasize one level over another to answer specific questions. Because my research focuses on Palaeo-Eskimo raw material selection strategies, for the remainder of this chapter, I emphasize the roles that lithic raw material availability and quality, and group mobility have in influencing the kinds of technological strategies toolmakers will use. The principal technological strategies available to toolmakers to deal with these factors include curation, expediency, and bipolar reduction. In combination, these causal factors and technological strategies are responsible for the variability seen in all lithic assemblages, including those of the Palaeo-Eskimos occupying the LeDx-42 site. Therefore, it is integral to understand the external forces that influenced Palaeo-Eskimo toolmakers in order to understand why they selected and used raw materials in the ways they did.

Technological Strategies

Curation

Curation, expediency, and bipolar reduction are the most commonly cited technological strategies used by hunter-gatherer toolmakers. Binford (1973, 1977, 1978, 1979) first defined *curated* tools as those that “once produced or purchased [were] carefully curated and transported to and from locations in direct relationship to anticipated performance of different activities” (Binford 1973: 242). Later, he further

emphasized that curation also included “the practice of maximizing the utility of tools by carrying them between successive settlements” (Binford 1979: 263). Expanding upon these definitions, Nelson (1991: 62) defined curation as “a strategy of caring for tools and toolkits that can include advanced manufacture, transport, reshaping, and caching or storing.” Curated tools are those which individuals invest a great deal of time and energy into their production, and the final products tend to be highly formalized in their morphologies. These formal tools are flexible (i.e. easily re-sharpened, altered and recycled; see Goodyear 1989; Parry and Kelly 1987; Andrefsky 1994b), and are prepared in anticipation of inadequate conditions (e.g. materials, time, facilities) so users are prepared at the time and place of use (Nelson 1991: 62, see also Torrence 1983). As a result, curation mitigates the problems of time stress, seasonality, mobility, and raw material availability.

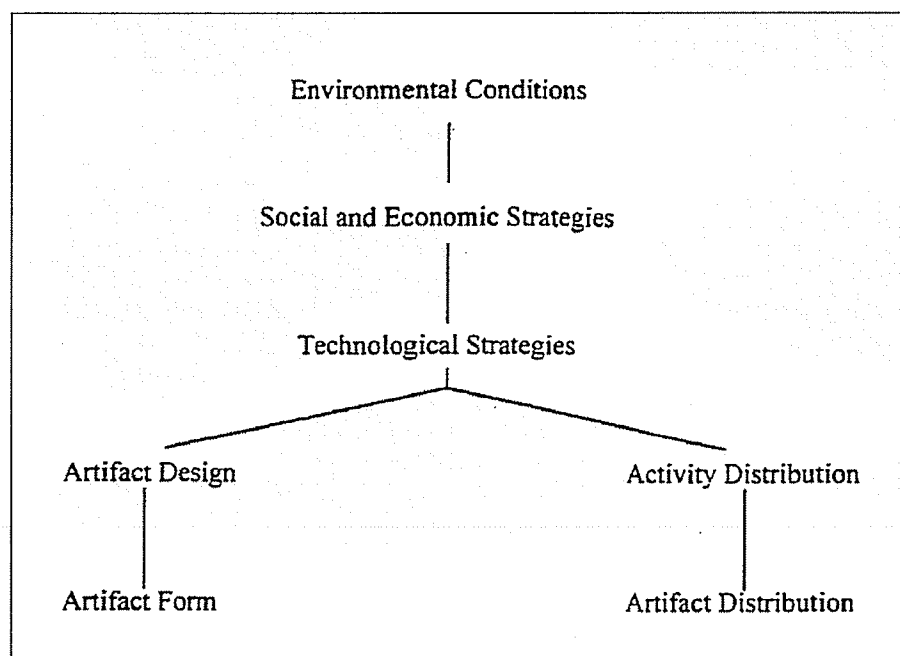


Figure 4.1 Levels of Analysis in the Organization of Technology (Nelson 1991: 59).

Expediency

Expedient tools are those which are manufactured, used, and discarded according to their user's immediate needs, and frequently this process occurs with a single event (Binford 1979: 267; Bamforth 1986: 38). They are technologically simple, unstandardized, and often raw material wasteful (Andrefsky 1994b: 23). Expedient tools tend to be present in conditions where time and place are predictable (Nelson 1991: 64; Parry and Kelly: 300). Nelson (1991: 64) has listed three conditions required for the implementation of an expedient technology: adequate supply of raw material, no time stress (Torrence 1983), and long term occupation or continued re-use of a location in order to make use of a raw material stockpiles, caches, or local abundances.

Bipolar Reduction

Bipolar reduction is yet another strategy used by toolmakers to produce usable tools. "[It] produces flakes by placing a core on a stone anvil and striking the core with a stone hammer at 90° (i.e. straight down), producing two opposing points of impact, one on either side of the core" (Jeske and Lurie 1993: 132). Bipolar strategies are often observed in conditions where there is a lack of good quality raw material (Andrefsky 1994a), when small cobble size and shape make other reduction strategies impossible (Andrefsky 1994a; Flenniken 1981; Knudson 1978), and when raw materials are not available in natural form, so existing toolkits are liquidated for usable flakes (MacDonald 1968; Ricklis and Cox 1993). While the final morphology of flakes produced in bipolar reduction is unpredictable, the technique does produce immediately usable flake tools or

the resulting flakes can be further modified into other tools (Jeske 1992: 472). It is a technique used by toolmakers to maximize available raw materials.

Causal Factors and Choice of Technological Strategies

Technological strategies are responsive to variable environmental, social, and economic factors. Archaeologists have described several of these factors, and the most common are mobility (Parry and Kelly 1987; Kelly 1988; Bamforth 1991), raw material availability (Ricklis and Cox 1993; Andrefsky 1994a/b; Beck *et al* 2002), and activity scheduling (Torrence 1983). The presence or absence of these causal factors plays an important role in the types of raw materials selected by toolmakers and how they are subsequently used. By studying them, archaeologists can gain valuable insight into the lives of past peoples and better understand their behaviours.

Activity Scheduling

Time stress (i.e. limitations on the time available to achieve a task) is an important factor in the formation of hunter-gatherer toolkits (Torrence 1983: 12). It is often necessary to schedule certain activities in order to avoid competition with others. When this is the case, parcels of time are divided and dedicated to specific tasks to ensure their successful completion and to maximize the use of resources that are only available for a limited time (Torrence 1983: 12).

When an important resource is temporally restricted, tool manufacture will be planned ahead of time, and tools will be manufactured in anticipation of use (Torrence 1983: 12). For example, caribou hunted by the Nunamuit are temporally restricted due to

their high mobility and seasonal availability. Because caribou were such an important subsistence resource to the Nunamuit, hunting tools were manufactured prior to the appearance of the animals. If tools were not prepared in advance, their manufacture and repair would detract from the already limited 'pursuit time' (see Schoener 1971) and risk successful capture of game (Binford 1977, 1978, 1979).

Temporal restrictions are not limited to subsistence resources; seasonality is also an important limiting factor in the availability of raw materials (e.g. Hayden 1989; Wenzel and Shelley 2001). In areas where stone is seasonally and environmentally restricted (e.g. snow cover, flooding), hunter-gatherer toolmakers had to become familiar with the environment in order to successfully collect raw materials from their source. When studying the Denbigh Flint Complex (4200-3500 BP) at the Mosquito Lake site in northern Alaska, Wenzel and Shelley (2001: 11) found that the regional climate had remained relatively uniform throughout the last 10,000 years. Therefore, it was possible to use climatic data collected in the present day for their study. From this, they found that during the winter months the ground could be frozen for as long as eight months from mid-September to mid-June, and determined that although lithic raw materials were available throughout their study area, the freezing winter temperatures restricted its procurement to the warmer spring/summer months (Wenzel and Shelley 2001: 11).

At the Emanon Pond site, a Paleo-Indian workshop-habitation site in New York located at the base of a bedrock outcrop of high quality Onondaga chert, Tankersly (1995) used present day and paleoclimatic data to determine the seasonal availability of stone in the region. In the present day, the ground at Emanon Pond is frozen and snow covered from the late fall to the early spring, and paleoclimatic evidence suggests that

these conditions would have been more extreme during the Paleo-Indian period (Tankersly 1995: 11). Following the spring thaw, the water table approaches the surface and does not drop enough to create a firm enough surface for humans to walk on until June (Tankersly 1995: 11). Therefore, the availability of stone at Emanon Pond is restricted to the summer months. Hunter-gatherers dealing with seasonal restrictions in raw materials, like those at Mosquito Lake and Emanon Pond, most likely dealt with the limited availability of toolstone by creating a curated technology. They invested their time and energy in creating a formalized, multi-purpose and, multi-function technological strategy that would conserve stone until the next scheduled encounter with a source area during the appropriate season.

Mobility

The degree of group mobility will also influence raw material selection and technological choice. Mobility is partially determined by the distribution and availability of resources, both lithic and non-lithic. However, because there is no relationship between these two resource types, a group's technology must "solve the problem, of spatial and temporal differences between the location of lithic raw materials and the location of stone tool use, while meeting the functional needs of the task(s) for which the tool is used" (Parry and Kelly 1987: 300; see also Bamforth 1986; Binford 1979; Kelly 1988). This means that if lithic raw materials are scarce in an area, toolmakers must compensate by creating a toolkit that will: (1) conserve raw materials until a new source area is encountered; and (2) last long enough to satisfy the technological needs of the individuals using them.

Mobile hunter-gatherers are the most likely to encounter spatial restrictions in the availability of raw materials because they occupy much larger territories than sedentary groups, and all of their scheduled tasks may not coincide with the presence of lithic source areas. Because tool needs usually cannot be predicted in advance, and lithic raw materials are simply too heavy for individuals to carry more than what is needed (see Beck *et al* 2002), mobile hunter-gatherers generally relied on formal technologies. Formal tools are multi-use, multi-function, easily altered, re-sharpened and/or recycled (Parry and Kelly 1987: 298), and are curated to maximum utility. Curtated technologies are generally finished or near-finished (i.e. blanks, performs) when they arrive at a site. Therefore, the debitage detached from tools will consist primarily of late stage finishing flakes. These flakes will generally be very small, exhibit no cortex, have high dorsal scar counts, and multifaceted or prepared platforms.

In contrast, sedentary groups tended to rely on expedient technology (Parry and Kelly 1987). Sedentary groups may have experienced spatial restrictions in raw material availability, but the longevity of their site occupations allowed for raw materials to be transported and stockpiled on-site (Parry and Kelly 1987: 301). When raw materials are abundant, whether naturally or unnaturally, there is little need to manufacture portable lithic tools. Tools simply needed to fulfil the immediate need of the user, and were most often discarded after a single use (Binford 1979: 267; Bamforth 1986: 38; Parry and Kelly 1987: 300). Because the tool needs of individuals employing expedient technologies are generally satisfied by simple, unaltered flakes with sharp edges, the associated debitage assemblage generally consists of early stage flakes. These flakes are large compared to those from later stages of reduction, generally exhibit significant

cortical cover because they represent the first flakes to be detached from a piece of stone (provided it derives from a cortical nodule), have a low dorsal scar count, and a single or unmodified platform.

Raw Material Availability: Transport

Andrefsky (1994a: 375; 1994b) has argued that the variability present in the material record can be partially accounted for by the differential availability of lithic raw materials. Geological factors such as the size, shape and quality of raw material will influence the final morphology of stone tools.

If raw material source areas are a great distance from a group's home, it is necessary for toolmakers to travel to the source to obtain stone. Hunter-gatherers will employ economically efficient strategies to mitigate the costs of travel and transport. Beck *et al* (2002) examined the costs of transport upon departure of a quarry using central place foraging models. Groups procuring subsistence resources have to choose whether to begin processing food items in the field or wait until they arrive home. The distances to be travelled between the exploitation area and base camp influence this decision. The greater the distances to be travelled, the more likely individuals are to process in-field. Processing in-field allows groups to maximize the amount of usable material transported in fewer trips. On the other hand, if the base camp is close, groups may simply choose to transport the material unprocessed to the residential site in multiple trips (Beck *et al* 2002: 486). Ultimately, individuals will make economically efficient choices concerning field processing and transport costs (Beck *et al* 2002: 486).

By measuring bifacial reduction at two quarries and their associated residential sites, Beck *et al* (2002) studied the costs of stone transport during the Paleoarchaic period (ca. 11500/11000-8000/7500 BP) in Nevada. The authors predicted that hunter-gatherers will gauge the amount of time they will spend processing materials by the distance to be travelled back to camp; the greater the distance, the more intensively the raw materials will be processed (Beck *et al* 2002: 495). The Little Smoky Quarry is located 60 km from its associated residential site, whereas the Cowboy Rest Creek Quarry is only 9 km from its residential site. As predicted, bifacial reduction was more intense at the Little Smoky Quarry than it was at Cowboy Rest Creek. Because of the 120 km round trip that groups were making to procure stone at the Little Smoky Quarry, groups probably felt it was more efficient to maximize the amount stone carried in a single trip rather than having to budget more time for subsequent return trips (Beck *et al* 2002: 498). Whereas, for those exploiting the Cowboy Rest Creek Quarry, it was probably easier to make multiple trips for stone rather than spending time away from home to process raw materials so they could be transported in a single trip (Beck *et al* 2002: 498).

Newman (1994) also found that there is a direct relationship between flake weight and thickness (flake length $\times$ width $\times$ thickness) and the distance to raw material source areas. He examined lithic debitage from raw material sources ranging from 2 to >200 km from the Pot Creek Pueblo (ca. 1250 AC) and Cerrita pithouse (ca. 1100 AC) sites in New Mexico in order to understand the nature of this relationship (1994: 401-5). With only a slight deviation in the coarsest of materials, Newman found that the size of lithic debitage from the most distant sources was smaller than debitage from closer source areas. This suggests that individuals were behaving economically; they conserved the

available raw materials in order avoid extra energy expenditure in returning to source areas to collect more toolstone (Newman 1994: 495).

Similarly, Ricklis and Cox (1993) found that during the Late Prehistoric (ca. 1200-1700 AD) Rockport phase on the central coast of Texas, technological strategies were heavily influenced by the relative proximity of sites to the only lithic source area in the region. The authors classified and examined debitage from all stages of reduction (i.e. primary, secondary, tertiary, and bifacial) to determine if distance influenced the types of technological strategies employed at a site (Ricklis and Cox 1993: 452). They found that the quantity of bifacial thinning flakes increased as sites became more distant (Ricklis and Cox 1993: 451). This was likely because individuals were trying to conserve stone and prolong the use-lives of their tools through edge rejuvenation of formal tools (Ricklis and Cox 1993: 452). However, the site furthest away from the lithic source was unlike the others because it contained very few formal bifacial thinning flakes. The authors believe that this may reflect the complete exhaustion of bifacial tools (Ricklis and Cox 1993: 452). When access to raw material is highly restricted, individuals will reorganize their technological strategies to cope with raw material stress. When costs are too great to return to a lithic source and all tools are exhausted, individuals will use other means to prolong the life of any remaining lithic material (e.g. heat treatment or liquidation of exhausted tools) or they will substitute other materials for stone (e.g. shell, wood, bone) (Ricklis and Cox 1993: 457; Parry and Kelly 1987: 302).

Raw Material Availability: Quality

The quality of raw materials will also influence technological strategies (Andrefsky 1994a/b). Quality refers to the ease with which raw materials can be flaked (Andrefsky 1994b: 29), and the flaking quality is influenced by the uniformity of the stone, the presence or absence of inclusions, flaws, or cracks within the stone, and the material's grain size (Crabtree 1975: 5, Andrefsky 1994b: 29). Fine-grained homogenous raw materials (e.g. obsidian, chert) fracture predictably because they are isotropic (uniform and identical in all directions). They are most often chosen for the manufacture of formal tools (Goodyear 1989: 4; Andrefsky 1998: 23, see also Chapter 3). Conversely, coarser and/or less homogenous raw materials are difficult to flake but in instances when it is successful, flake removal is often unpredictable. Therefore, tools that require less skill and craftsmanship are often manufactured from low quality raw materials (Andrefsky 1994a: 383, 1994b)

The size of raw materials is another variable of equal importance to quality when determining what technological strategy to use (Andrefsky 1994a). Archaeologists have shown that the size of a blank (i.e. a usable piece of lithic material of appropriate size and quality to produce an artifact, Kooyman 2000:47) will determine the size of the formal tool produced (e.g. small tools come from small blanks, and big tools come from big blanks) (Lothrop 1989; Kuhn 1992). Therefore, it is possible to assume that the size of naturally occurring raw materials will influence the final shape and size of the tools produced from them. Additionally, raw material size and shape will influence the kinds of strategies used to manufacture tools (Andrefsky 1994a: 384). When raw materials are too small for most reduction strategies (e.g. bifacial or prepared core reduction) bipolar

reduction is often used to maximize the available raw materials and produce as many usable flakes as possible (Andrefsky 1994a: 384)

As mentioned above, Andrefsky (1994b) has shown that the availability and quality of lithic raw material plays an important part in the production of stone tools. Indeed, Andrefsky (1994b) believes that stone availability and quality may be the most important determining factors in the organization of a group's technology. Consequently, he dismisses the notion that mobility and settlement are the ultimate factors determining the selection of reduction strategies (i.e. mobile groups use formal technologies while sedentary groups use informal/expedient technologies). To demonstrate this, he presents three case studies from the western United States that illustrate the importance of raw material availability and quality in the production of tools. Additionally, because both mobile and sedentary groups have occupied the sites studied, Andrefsky is able to demonstrate that settlement type is not a determining factor in the selection of technological strategies.

The first site is located in an area known as Pinon Canyon in Colorado. High quality raw materials are available in abundance in the area. Both formal and informal tools were made from locally available raw materials in roughly equal proportions. The second site is located in the Calispell Valley in Washington State. Here, only low quality raw materials are available and even these are scarce. Local raw materials were used to make some informal tools, but most tools were formal and made from higher quality non-local materials. The final site is located in the Rochelle Archaeological District of Wyoming where poor quality raw materials are available in abundance. The majority of

tools were informal and made from local stone, while only a few formal tools made from non-local stone were present.

From these data, it is apparent that settlement type does not necessarily dictate technological strategy. In the Calispell Valley, sedentary groups used formal technologies, and in Pinon Canyon mobile groups made use of informal tools in equal proportion to formal tools (Andrefsky 1994b: 30). It is raw material availability and quality that determined their patterns of use. When raw materials are scarce, groups will procure non-local raw materials to fashion long-lasting, versatile and heavily curated tools. However, when raw materials are abundant, it is the quality that will influence the types of tools made. Poor quality stone is difficult to flake and is typically fashioned into informal tools whereas high quality raw materials are much easier to work and fracture predictably. Therefore, high quality materials are typically chosen to manufacture more intricate formal tools (Andrefsky 1991; 1994b). Andrefsky (1994b: 30) has shown that when the availability and quality of raw materials are considered a predictable pattern of tool production will emerge (see Figure 4.2).

Toolmakers rely on a variety of technological strategies to cope with the unique environmental, social, and economic factors present in their landscape. Archaeologists have described several of these factors, and the most common are mobility, raw material availability, and activity scheduling. The presence or absence of these causal factors ultimately influences the types of raw materials selected by toolmakers and how they are subsequently used. Therefore, it is through the detailed analysis of the technological strategies employed by a group that archaeologists will be able to more fully understand the behaviours and cultural systems of the people they study.

		Lithic Quality	
		High	Low
Lithic Abundance	High	Formal and Informal Tool Production	Primarily Informal Tool Production
	Low	Primarily Formal Tool Production	Primarily Informal Tool Production

Figure 4.2 Showing the relationship between the quality and abundance of raw materials and the kinds of tools produced from them (Andrefsky 1994b:30)

Hypotheses and Test Expectations

Within the Palaeo-Eskimo cultural continuum, the Pre-Dorset culture presumably transitioned into Dorset around 2800 – 2500 BP (Helmer 1994); however, the nature and catalyst of this change remains a point of controversy and debate among Arctic researchers. Some archaeologists have made inferences about Palaeo-Eskimo social organization from their patterns of raw material selection. They have agreed that these patterns changed over time with Pre-Dorset relying more on locally available materials while Dorset chose to use finer quality exotic stones (Maxwell 1973: 300; Nagy 1997: 198). Nagy (1997, 2000) and McGhee (1996) have even suggested that differential selection of stone was a measure of social complexity. The LeDx-42 site contains securely dated test units spanning all three major periods in the Palaeo-Eskimo cultural continuum (Pre-Dorset, Transitional, and Dorset). The debitage contained in these test units will allow me to assess patterns of variability in Palaeo-Eskimo raw material

selection and use within each culture period at the site. I have constructed three working hypotheses and outlined their related test expectations to evaluate what kinds of raw material selection strategies were being used by the Palaeo-Eskimos at LeDx-42, and to assess whether or not these strategies changed over time.

Hypothesis 1

This hypothesis states that there was no change in raw material selection strategies at LeDx-42 throughout the Palaeo-Eskimo occupation of the site. This would imply that the Palaeo-Eskimos returned to this site for millennia to exploit locally available lithic raw materials. Moreover, it would support the notion that a radical shift in technological organization and preference for exotic toolstone did not occur between the Pre-Dorset and Dorset periods. If the same local sources were exploited during the Transition period, it would suggest that despite presumed changes in the local climate that the Palaeo-Eskimos still maintained a consistent seasonal exploitation strategy where they traveled to the interior to renew their toolstone supplies. Moreover, it would also suggest that the Dorset maintained long distance inland travels despite the assumption they became more sedentary and coastal oriented with the onset of a colder climate (see Milne *et al* 2008a).

Test Expectations

If this hypothesis is valid, the geochemical signatures of debitage from each cultural assemblage will correspond with the geochemical signatures of locally available raw material. The case will be the same for the colour, quality, and texture of the

debitage assemblages and locally available materials – they will be positively correlated. Because the raw materials being reduced are locally available and in nodular form, the lithic debitage should contain high frequencies of cortical flakes. Moreover, since toolmakers would be exploiting locally abundant stone, I would expect that the debitage in each dated unit would be dominated by larger flakes displaying attributes associated with early to middle stage reduction (e.g. minimally modified platforms, pronounced bulbs of percussion and compression rings, ecrasse scars, low dorsal scar counts).

Hypothesis 2

This hypothesis states that there was a change in the raw material selection strategies at the LeDx-42 site between the Pre-Dorset and Dorset occupations. This would imply the Pre-Dorset were returning to LeDx-42 to exploit locally available raw materials, while the Dorset relied on distant lithic sources to fulfil their technological needs. In order to acquire these non-local and/or exotic raw materials, the Dorset either adopted new mobility patterns and travelled directly to the source, or they developed exchange networks. This hypothesis supports the claim that a radical shift in technological strategies and a preference for exotic raw materials occurred between Pre-Dorset and Dorset. During the Transitional period, we should expect to see the emergence of new types of raw materials. Specifically, a gradual shift towards exotic raw materials would emerge. Additionally, a shift away from local lithic resources would indicate that the function of the site changed. Because occupants were no longer travelling inland to procure locally available lithic resources, the occupation of LeDx-42 would most likely be related to subsistence or social requirements. This change could

either be the result of regional climate change or increased social complexity and familiarity with the landscape (see Nagy 1997, 2000). It could also be linked to the development of long distance trade networks with other Dorset populations, as Odess (1998) has suggested.

Test Expectations

If this hypothesis is valid, the Pre-Dorset and Dorset lithic assemblages will be markedly different. Specifically, the Pre-Dorset sample will be dominated by local sources with the debitage and raw samples sharing the same geochemical signatures. Because the Dorset would be selecting non-local stone for tool manufacture, the geochemical signatures derived from debitage in these dated units would be different from those of the locally available raw material found in the Pre-Dorset units. The non-local stone would also be of higher quality and texture than the locally available stone, and the debitage deriving from the non-local stone would tend to be smaller with less cortex than flakes derived from locally available raw materials. These non-local toolstone flakes should also display attributes associated with late stage reduction and a curated technological strategy (i.e. advanced states of platform preparation, diffuse bulbs of percussion and compression rings, high dorsal scar counts). There will also be a marked difference in the colours of the local and non-local stone where the debitage flakes from distant sources are entirely different from any of the local raw chert samples. Debitage colour categories during the Pre-Dorset period should match those of the locally available raw materials. However, during the Transition period, distinctive colour

categories are expected to appear, and by the Dorset occupation it is expected that they will dominate the lithic assemblage.

Hypothesis 3

This hypothesis states that there are no discernable patterns of raw material exploitation at the LeDx-42 site that can be used to distinguish differences in selection between the Pre-Dorset, Transitional, and Dorset occupations. In other words, the cherts being worked are entirely random with both local and non-local sources being used throughout the entire cultural continuum. This might suggest that the site was not being re-occupied for the purpose of raw material acquisition. Rather, it could have been occupied for social or subsistence purposes. This would mean that there are other locations in the southern Baffin region where chert toolstone could also be reliably procured. It could also mean that there is another source area in the interior that we do not yet have raw samples for. If the proportions of non-local and/or exotic raw materials are consistent throughout the occupation, it could likely be the result of an explicit cultural choice by the Palaeo-Eskimos to serve a specific social (see Ellis 1989; Hayden 1982), or technological (see Goodyear 1989) purpose. However, if the distribution of raw materials is random, it may indicate that raw material types were either unimportant to the Palaeo-Eskimos, or the value of certain types of raw materials changed with each occupational period.

Test Expectations

If this hypothesis is valid, no discernable patterns will be present in the Pre-Dorset, Transitional, and Dorset assemblages. If the Palaeo-Eskimo were selecting both local and exotic raw materials, some of the geochemical signatures for debitage will match locally available raw materials while others will be distinct. The case will be the same for the frequency and proportion of debitage colour categories; some will match local raw materials while others will be distinct. The frequencies at which raw materials are selected will be different in each cultural period. If local and exotic raw materials are both available and of relatively good quality, toolmakers will manufacture formal and informal tools in the same proportions (see Andrefsky 1994a). Therefore, the debitage assemblage will contain the full range of variability; flakes from early, middle, and late stage reduction will be present. Cortex will be present on those flakes associated with early stage reduction, and almost entirely absent on those from middle and late stages.

Chapter 5

Research Methodology

This study comprises two analytical components. The first involves the use of individual attribute analysis to observe the macroscopic attributes of lithic debitage flakes from securely dated excavation units at the LeDx-42 site, and raw material samples collected in the vicinities of Mingo and Amadjuak Lakes in the interior of southern Baffin Island. Second, I use microscopic petrography and trace element analysis on the selected debitage and raw material samples to assess how many local geological sources may exist in these regions and which ones were being exploited by the Palaeo-Eskimos who occupied the area for millennia. This chapter discusses the study samples, the respective analytical methods used to examine them, and the procedures followed to prepare them for analysis.

Study Samples

This study focuses on lithic debitage and raw samples of chert. Debitage was selected for analysis because it is typically the most abundant artifact class found on a site (Andrefsky 1998; Odell 2004). Debitage is also the immediate by-product of stone tool manufacture given its reductive nature and it is rarely, if ever, removed from a site

for use elsewhere (Cahen and Keeley 1980:169). Therefore, lithic debitage leaves an enduring record of the kinds of technological activities that were undertaken at a site and the range of raw materials that were being worked by toolmakers (see Andrefsky 1994, 1998; Gramly 1980; Ingbar 1994).

The raw materials used in this study were collected from the Mingo and Amadjuak Lake Districts of southern Baffin Island by Milne in 2004, and Milne and myself in 2007. Samples were surface collected and chosen based on their distinctive visual characteristics. Raw materials are examined in order to test the assumption that Palaeo-Eskimos were travelling to the interior in order to exploit locally available lithic.

Through her ongoing research, Milne (1999, 2003, 2005a, 2008; Milne and Donnelly 2004) has established that the interior was also an important place for the Palaeo-Eskimo to procure toolstone. However, her analyses relied on macroscopic visual characterization to establish lithic source groups for locally available raw materials and the artifacts derived from them. As discussed below, visual methods of analysis are subject to interpretive bias and are therefore not entirely reliable. Using samples collected in 2004 and 2007, I will further test the assumption that Palaeo-Eskimos were travelling inland for raw materials using two objective analytical methods: microscopic petrography and trace element analysis. These analyses will allow me to unequivocally determine if Palaeo-Eskimos were returning to the area throughout the cultural continuum to exploit locally available raw materials, and if their patterns of selection and use changed over time.

Only debitage from securely dated test units is used in this analysis, so the integrity of each occupational period is maintained as much as possible. The Pre-Dorset

sample is from a single test unit (Test 4, N=1081), the Transitional sample from three test units (F11, N=1839; U3, N=531; Test 2, N=3436), and the Dorset sample from two test units (Test 9, N=23; Test 11, N=10). In total, 6920 flakes are included in this analysis. A detailed discussion of how raw material and debitage specimens were sampled and prepared is presented below.

Chert Formation

Chert is a fine-grained, dense, and commonly very hard rock composed primarily of the minerals quartz, chalcedony, and opal (Blatt *et al* 1980: 571, Boggs 1992: 583). While cherts are primarily composed of SiO₂, they frequently contain minor impurities consisting of clay minerals, calcite, hematite, dolomite, and organic matter (Blatt *et al* 1980: 571, Boggs 1992: 583). More commonly, however, they include minor amounts of Al, Fe, Mn, Ca, Na, K, Mg, Ni, Cu, Ti, Sr, and Ba, and trace amounts of rare earth elements (Boggs 1992: 586). The amount of SiO₂ varies in each type of chert, ranging from 90% to more than 99% in very pure cherts (Luedtke 1992). Most of the impurities in chert were present in their original depositional environment and later became incorporated during formation. It is from these impurities that each type of chert achieves its distinctive visual characteristics (Luedtke 1992: 38).

Observational Methods

Macroscopic Analysis

Archaeologists most often rely on a stone's macroscopic (i.e. visible to the naked eye) characteristics to define its provenance. The colour, quality, texture, and density of

stone are the most commonly used characteristics in visual sourcing studies (e.g. Ferguson and Warren 1992; Moholy-Nagy and Nelson 1990). This type of analysis is popular because it is simple and inexpensive, and can be quite accurate when the raw materials display distinctive patterns and textures that make them easy to classify and compare to other raw materials. Well known examples of distinctive cherts include Knife River Flint from North Dakota, Ramah Chert from Labrador, and Southampton Island banded chert from the Arctic island of the same name. However, not all archaeologists are so lucky to have visually distinctive raw materials like these in their research assemblages. In a study performed by Moholy-Nagy and Nelson (1990) where both geochemical and visual methods were used, objective geochemical analysis showed that almost half of their samples were classified incorrectly using visual analysis. This is not surprising as it has been shown that lithic materials from different geological formations and different geographic areas can be visually identical or that a range of physical properties (e.g. colour, lustre, texture) can occur within the same source (Malyk-Selivanova *et al* 1998: 676). Furthermore, studies using visual characterization will always suffer from interpretive bias because archaeologists are forced to make subjective assessments of the stones to create groupings they believe are representative of the original source (e.g. Ahler 1989a/b; Larson 1994:58; Luedtke 1978:745; Odell 2004:30-31).

Individual Attribute Analysis

Individual attribute analysis (IAA) is a popular observational method used by archaeologists to measure the technical, morphological, and functional variability present

in artifact assemblages (e.g. Andrefsky 1998; 2001; Bradbury and Carr 1995, Magne 1985; Odell 2004; Sullivan and Rozen 1985). IAA begins with the selection and definition of artifact attribute states. The attribute states used in every study will vary according to the question(s) being asked and the researcher who is asking them (Sullivan and Rozen 1985). In this study, I am attempting to isolate if and to what extent raw material selection strategies used by the Palaeo-Eskimos varied over time at LeDx-42. Therefore, I chose to record the colour, quality, texture, and cortex of raw materials. These distinctive attributes should allow be to qualify the different raw material source groups present in the artifact assemblage.

The visual appearance of chert is largely the result of its depositional environment. It is assumed that every depositional environment for chert is unique. Therefore, the qualitative attributes of each source of chert (i.e. colour, quality, texture) are assumed to be unique to that source, thus making visual characterization possible (Moholy-Nagy 2003: 303). However, as noted above, this is not always the case (see Malyk-Selivanova 1998)

Cortex is used to determine stages of lithic reduction (Magne 1985: 115, 1989: 17; Andrefsky 1998: 112; Odell 2004: 126; Bradbury and Carr 1995: 101). The amount of cortex present on a flake will proportionately decrease as a piece of stone is reduced. Flakes with the most cortex are attributed to the earliest stages of reduction, and those with the least to the latest stages (Andrefsky 1998: 112). However, because cortex is usually only present in the earliest stages of reduction, it has been generally accepted that cortical cover can only be used to verify the presence of primary reduction on a site (Magne 1989: 17; Mauldin and Amick 1989: 69). The physical properties of raw

materials will also influence the amount of cortex present in a lithic assemblage (Sullivan and Rozen 1985: 756). For example, raw materials extracted from a bedrock outcrop will likely have no cortex at all while a secondary nodule of chert from a river bed is likely to be entirely encased. Furthermore, the size of the parent material being reduced will influence the amount of cortex present in the final lithic assemblage. The debitage produced in the reduction of a large nodule of stone will contain fewer cortical flakes overall than those produced in the reduction of a smaller nodule (Sullivan and Rozen 1985: 756; Bradbury and Carr 1995: 196). The amount of cortex present in every lithic assemblage will vary according to these factors. Therefore, it is integral for researchers to be familiar with the types of stone being used for lithic reduction and their physical properties (see Bradbury and Franklin 2000).

Microscopic Analysis

Petrographic analysis is a simple, relatively inexpensive technique that provides information on the texture, mineralogy, and fossil content of lithic materials through microscopic analysis of thin sectioned stones (Lavin and Prothero 1992: 102). It is often employed by archaeologists in sourcing studies where the macroscopic physical properties of a raw material are not unique enough to accurately attribute them to a source. Much like macroscopic analysis, petrography relies on the identification and comparison of source attributes and is thus subject to the same interpretive bias. In order to reduce the degree of subjectivity, a reference guide containing pictures of various raw material types, and the minerals and internal structures often associated with them is used

to aid in the classification of samples. In this study, *The Atlas of Sedimentary Rocks Under the Microscope* (Adams *et al* 1984) was used.

Geochemical Analysis

Geochemistry, the study of the distribution of the various elements in rocks and minerals, can provide researchers with a chemical fingerprint of a stone sample. From this we can learn about the formation and depositional contexts of various lithic raw materials and begin to define source areas (Luedtke 1992: 39). The use of geochemical techniques to characterize the elemental composition of lithic materials has been gaining momentum in archaeology over the last few decades (e.g. Evans *et al* 2007; Hess 1996; Hoard *et al* 1992; Hoard *et al* 1993; Jarvis 1988; Leudke 1978; 1979; Malyk-Selivanova *et al* 1998; Meyers 1984; Morrow *et al* 1992; Norman *et al* 1989; Spielbauer 1984). The instruments most commonly used in chert sourcing studies are x-ray fluorescence (XRF), instrumental neutron activation analysis (INAA), and inductively coupled plasma (ICP) analysis. Each technique varies in its cost, availability, ease of application, and sensitivity to particular elements; therefore, some techniques will be better suited for some research questions and raw materials than others (Andrefsky 1998: 42; Jarvis 1988: 5; Odell 2004: 33).

INAA is by far the most commonly used instrument to source chert (e.g. Hess 1996; Hoard *et al* 1992; Hoard *et al* 1993; Jarvis 1988; Luedtke 1978, 1979; ; Malyk-Selivanova *et al* 1998; Meyers 1984; Morrow *et al* 1992; Spielbauer 1984). Purdy (1981: 120) defines INAA as:

...chemical analysis by means of induced radioactivity to make use of nuclear reactions resulting in radioactive species of atoms, whose disintegration characteristics are subsequently determined and used as a basis for identifying the elements originally present in the sample.

INAA provides both a qualitative and quantitative analysis; it is precise, quick, and sensitive of up to 50 elements (Church 1994: 51; Odell 2004: 33). However, the technique also has several disadvantages. While some call the technique non-destructive (Church 1994: 51), material is often broken into small pieces for sampling and these sometimes remain radioactive for a long time (Odell 2004: 33). Moreover, INAA is costly, the availability of nuclear reactor centres in which to conduct analysis is limited (Odell 2004: 33), and analysis may lead to the chemical alteration of the sample (Church 1994: 51) thus presenting curatorial challenges once a study is complete since the samples effectively become radioactive.

ICP analysis is relatively new to archaeology, but is slowly being adopted by researchers. In ICP analysis, samples are ionized by placing them in a solution that is heated until it becomes plasma (Andrefsky 1998: 44; Odell 2004:40). At this point, two types of analysis are possible: optical emission spectroscopy (ICP-AES), and mass spectrometry (ICP-MS). In ICP-AES analysis, the high energy elements in the plasma emit wavelengths that are split up and detected in a photomultiplier tube and analyzed by computer. In ICP-MS analysis, the ions in the plasma are introduced to a mass spectrometer and separated based on their mass (Odell 2004: 40).

Recently, a study was undertaken by Evans *et al* (2007) to see if it was possible to chemically determine the sources of four different black cherts from northern England. Two of the samples were from southern Pennines, and the remaining two from northern

Pennines. Using ICP-AES, ICP-MS, and laser ablation ICP-MS (LA-ICP-MS) to determine the trace element concentrations of the cherts, the authors found that it was possible to distinguish the northern sources from the southern. Further, they found that while the two sources from southern Pennines are geologically unique, the two black cherts from the north are derived from a single continuous bed of chert (Evans *et al* 2007: 2167). The authors also tested a small number of archaeological specimens and were able to successfully attribute them to the established source areas (Evans *et al* 2007: 2167).

The results of this study are very promising for my own research. The goal of the present study is to determine the number of geological sources present in the interior of southern Baffin Island and to isolate the types of raw materials being exploited by the Palaeo-Eskimos. This study is done by comparing archaeological specimens with locally available raw materials. In their preliminary study of black cherts in northern England, Evans *et al* (2007) found that this type of source determination is possible.

Secondary Ion Mass Spectrometry

The application of secondary ion mass spectrometry (SIMS) is another comparatively new endeavour in archaeology. It has been successfully applied to source turquoise (Hull *et al* 2008), and preliminary tests on chert indicate that it has the potential to distinguish unique source fingerprints for this complicated stone (Milne *et al* 2007a/b). The results of these preliminary chert studies are being expanded upon in this study.

In SIMS analysis, the surface of the sample is bombarded with a beam of primary ions. Upon impact, atoms and molecular fragments are ejected, and a small fraction of

these are ionized. This is known as *sputtering* (Hervig *et al* 1992). These secondary ions are then focused into a mass spectrometer (Dowsett and Adriaens 2004: 2; Ireland 1995: 3). In turn, these secondary ions provide detailed information about the composition of the sputtered area, including the elemental and isotopic composition, which can ultimately lead to a distinct chemical or isotopic fingerprint (Dowsett and Adriaens 2004: 2). Therefore, the SIMS technique can provide both isotopic (e.g. $^{18}\text{O}/^{16}\text{O}$) and chemical analysis (e.g., trace elements) from a single analytical spot.

There are several advantages to using SIMS to source chert. It provides quantitative analysis of elemental ratios (Spoto 2000:158), and does so with a great deal of precision measuring in the ppm to ppb range. This, in turn, facilitates trace element analysis (Dowsett and Adriaens 2004:2) and the measurement of isotopic ratios both of which are crucial for assessing source provenance. Lastly, it is minimally destructive since it requires very small samples (~10nm). Moreover, unlike INAA, SIMS samples do not require any special post-analysis curation since this process does not chemically alter the sample (Church 1994:51).

Lithic Sourcing in the Arctic

Only a handful of the raw material sourcing studies that have been done in the Arctic have used objective geochemical techniques (e.g. Gramly 1978; Lazenby 1980; Malyk-Selivanova *et al* 1998 for chert; Cook 1995 for obsidian). Sourcing studies in Labrador have used petrographic and geochemical techniques to “fingerprint” lithic materials, determine their geological sources, and map the cultural movement of the materials (Gramly 1978; Lazenby 1980). Lazenby (1980) examined four types of stone

whose distinctive visual attributes usually allowed for easy identification, but not always. On occasion, Ramah and Cod Island cherts, and Ryan's quartz and Saglek quartzite were confused by archaeologists (Lazenby 1980: 635). Through microscopic examination of thin sections, differences in each stone type could be quantified by grain size, texture, and structure, as well as essential and accessory mineralogy. Additionally, Lazenby (1980) used INAA to see if trace elements could distinguish each type of stone and to determine the range of variability in the element content of each lithic type. Twenty-five trace elements were determined, but only 15 had significant enough concentrations to be of any use in distinguishing samples (Na, Sc, Cr, Mn, Fe, Co, Sb, La, Ce, Sm, Eu, Yb, Lu, Hf, U). Based on the recovered data, she found that while Saglek quartzite was distinguishable from the cherts, analysis was inconclusive for Ryan's quartz. Further, Ramah and Cod Island cherts could not be distinguished from each other by trace element concentrations alone (Lazenby 1980: 644).

Malyk-Selivanova *et al* (1998) also used INAA, electron microprobe, X-ray diffraction, and visual (micro and macro) analysis to study chert sources in northwestern Alaska. Knowing that chert is a highly variable stone (at both the intra- and inter-source levels), the authors use a "geological-geochemical" approach where it is assumed that a chert artifact created from a specific chert layer is identical to that layer and inherits its chemical and petrological features (Malyk-Selivanova *et al* 1998: 676). Knowing this, representative samples were taken from each source to cover the range of variability present within most chert sources. In determining the range of variability within each chert source, the authors were able to combine the results into a single data set. The authors then used these "geochemical quarry fields" to connect artifacts to individual

sources (Malyk-Selivanova *et al* 1998: 704). Archaeologically, this was important because it allowed the authors to discern which cultures were exploiting specific sources, and how and where chert was moving in prehistoric Alaska (Malyk-Selivanova *et al* 1998: 700).

Research Methodology

Raw Samples

Raw samples were separated into two discrete categories based on their respective collection locations: Mingo Lake (ML) and Mingo River (MR). Within each of these locational groupings, samples were further subdivided using the following attributes: colour (emphasized), quality, and texture. Colour categories were established using a Munsell Soil Colour Chart (1992). When a stone displayed multiple colours, the combined colours were recorded as a discrete colour category (Table 5.1). After each category was established, two or three representative stones were selected from each group, photographed, and subjected to petrographic and trace element analysis.

Debitage

Thedebitage assemblage was first subdivided into three discrete groups based on temporal period (i.e. Pre-Dorset, Transitional, and Dorset), and then further subdivided by test unit. Finally, individual flakes from each test unit were examined using the raw material attribute states listed in Appendix A. Once again, colour categories were established using a Munsell Soil Colour Chart (1992). When a flake displayed multiple colours, the combined colours were either recorded as a sub-group of a larger category, or

as a discrete colour category (see Table 5.2). After each category was established, representative stones were selected from each group, photographed and subjected to petrographic and trace element analysis (discussed below).

Table 5.1 Colour classifications of raw samples used in the study.

Groups	Colour Category	Comments
ML-1	Light olive brown (hue 2.5Y, 5/3)	Homogeneous
ML-6	Yellowish Brown (hue 10YR, 5/4)	Homogenous
ML-8	Light gray (hue 2.5Y, 7/2)	Homogenous
ML-18	White (hue gley N8/), bluish gray (hue gley 5B 6/1)	Homogenous, Iridescent
MR-1	White (hue gley, N8/), Light gray (hue gley, N7/)	Mottled
MR-3	White, (hue gley, N8/), Light olive brown (hue 2.5Y, 5/3), Light gray (hue 7.5YR, 7/1)	Mottled

Although, IAA was performed on debitage from the Pre-Dorset, Transitional, and Dorset periods, only flakes from Pre-Dorset and Transitional were sampled for petrographic and trace element analysis. Flakes from the dated Dorset units were excluded because they were simply too small and friable to undergo thin sectioning. The flakes selected for petrographic and geochemical analysis were photographed and analyzed for patterns of technological, functional, and morphological variability using the attributes listed in Appendix B. This analysis was required since preparing the flakes for petrographic and trace element analysis is a destructive process. Although the goal of this research is not to conduct a detailed technological analysis of debitage from LeDx-42, the attributes recorded for debitage undergoing destructive analysis will minimally provide some insights on the technological strategies used to reduce the different types of raw materials at the site and determine if some stones were being treated differently

because of their qualitative attributes (e.g. quality, colour, texture). Technological strategies are, in part, determined by the type and qualities of the raw materials being used. Therefore, if there was a change in raw material selection over time, it should be represented in the technological strategies used by toolmakers and their treatment of different toolstone types at the site.

Thin Sections

All representative samples of raw chert were selected from their respective source groups and photographed. The desired plane of cut was marked on each sample selected for petrographic analysis. On each stone, the ideal plane of cut encompassed all of the variability present in the stone (i.e. colour, quality, and texture). If a specimen's variability could not be captured in a single cut, then multiple cuts were made. Four raw material samples (ML-6, ML-18, MR-1, MR-3) were sent to Activation Laboratories Ltd. in Ancaster, Ontario where they were made into standard petrographic thin sections that are approximately 30µm thick.

In total, debitage from 17 of the 24 debitage categories were selected and 18 flakes were prepared and thin sectioned (S1, S2, S3, S4, S5a, S5b, S6, S8, S11, S12, S13, S15, S16, S18, S20, S21, S22, S24) by myself in the Bioanthropology Digital Image Analysis Laboratory (BDIAL) located at the University of Manitoba. Two additional raw material samples (ML-1, ML-8) were also prepared and thin sectioned in BDIAL. A representative sample was selected from each of these established colour categories for thin sectioning. However, some of the debitage were too small and friable to be thin

sectioned (S7, S9, S10, S14, S17, S19, S23). Therefore, the categories they represent were not included in the geochemical component of this study.

Table 5.2 Established colour categories used to classify lithic debitage into visual source groups.

	Colour	Comment
1	Light gray (hue 10YR, 7/1)	Some flakes mottled
2	Gray (hue 5Y, 5/1), with light gray (2.5Y, 7/2)	Some flakes mottled
3	Light gray (hue 2.5Y, 7/2), with light brownish gray (hue 10YR, 6/2)	Homogenous
4	White (gley, 8/), tinged dark reddish gray (hue 2.5YR, 5/1)	Iridescent, 2 flakes mottled
5	White (gley, 8/)	2 flakes mottled
6	Light olive brown (hue 2.5Y, 5/3)	Homogenous
7	reddish gray (hue 10R, 5/1), light brownish gray (hue 2.5Y, 6/2)	Swirled
8	gray (hue 5Y, 5/1), light gray (hue 2.5Y, 7/2), gray)hue 10YR, 6/1)	Banded
9	Dark gray (hue 2.5Y, 4/1), grayish brown (hue 2.5Y, 5/2)	Mottled
10	Yellowish brown (hue 10YR, 5/4)	Homogenous
11	Banded – dark gray (hue 5Y, 4/1), white (hue 5Y, 8/1)	Banded
12	Gray (hue 10YR, 6/1), with gray (hue 5Y, 5/1)	Mottled
13	Dark gray (hue 5YR, 4/1)	One flake mottled
14	White (hue 5Y, 8/1), gray (hue 5Y, 5/1)	Mottled
15	Light gray (gley N6)	Homogenous
16	Grayish brown (hue 2.5Y, 5/2)	One flake mottled
17	black (hue 5Y, 2.5/1), gray (hue 2.5Y, 5/1)	Banded
18	Light yellowish brown (hue 2.5Y, 6/3)	Homogenous
19	White (gley, N8), gray (hue 5Y, 5/1), light yellowish brown (hue 2.5Y, 6/3) (was 25)	Mottled
20	White (gley, N8), light gray (hue 7.5YR, 7/1)	Mottled
21	Light gray hue 2.5Y, 7/1), with white (gley, N8)	Some mottled
22	Pale Yellow 2.5Y, 7/4)	Homogenous
23	Pinkish Gray (hue 7.5Y, 7/2)	Homogenous
24	Black (hue 5Y, 2.5/1)	Homogenous

Each sample was first thoroughly cleaned using distilled water. The desired plane of cut was marked using a permanent marker. Each sample was embedded in epoxy-resin, placed in a vacuum to remove any air bubbles, and allowed to harden for 24 hours. The sample was then cut using a Buhler IsoMet diamond-edge saw. After each cut, the saw and water chamber were cleaned using distilled water to ensure that samples were not contaminated. Samples were then polished by hand using distilled water and 320, 600, 2400, and 4000 grit sandpaper and Buhler 0.05-micron aluminum paste, distilled water and a buffing mat until no scratches were apparent on the specimen and the surface appeared as glass. Samples were then rinsed using distilled water and placed in a sonic bath of distilled water for 10 minutes to remove any debris. Samples were mounted to a glass slide using epoxy-resin and left to dry for 24 hours. Each slide was de-bulked and ground into thin sections using the petro-thin machine. Samples were once again polished by hand using distilled water and 600, 2400, and 4000 grit sandpaper, and Buhler 0.05-micron aluminum paste, distilled water and a buffing mat until no scratches were apparent on the specimen and the surface appeared as glass. Finally, each sample was rinsed with distilled water and placed in a sonic bath with distilled water for 10 minutes to remove any remaining debris.

Trace Element Analysis

The six raw material samples (ML-1, ML-6, ML-8, ML-18, MR-1, MR-3) selected for trace element analysis were sent to Activation Laboratories for ICP-MS analysis. The concentrations of 64 elements were determined. The mottled samples (MR-1 and MR-3) were separated according to their visible colour characteristics and

each individual colour category underwent its own trace element analysis. The trace element concentrations of the 18 debitage samples were determined using SIMS analysis.

Secondary Ion Mass Spectrometry

When petrographic analysis was complete, each slide was cut to fit into the standard SIMS mount. Each sample was placed in a sonic bath of ethanol for 5 minutes, the desired locations of analysis marked using a permanent marker, and a ~200 Å thick Au coat was sputter-deposited on the surface of each sample using an Ernest F. Fullham No. 18930 Effacoater to ensure a surface conductivity of 5-10 ohms/cm during analysis.

The trace element concentrations of ^{27}Al , ^{92}ZrO , and ^{69}GaO were collected using the CAMECA ims 7F secondary ion mass spectrometer located in the Department of Geological Sciences' Mass Spectrometry Laboratories at the University of Manitoba. Measurements were taken using a ~12 nA primary ion beam of O^- ions on a 10 µm spot. A mass resolving power of ~350 was sufficient to limit isobaric interference to 0.1%. Sample voltage was 10 kV, with a primary acceleration voltage of -12.5 kV, and an overall impact energy of 22.5 kV. The ion detection system consisted of a Balzers electron multiplier coupled with an ion counting system with a deadtime of 25 ns. The secondary ions were detected by switching the magnetic field. At least two spots per location were collected from each sample. All data were corrected for using the NIST 614 Glass Standard and presented in ppm (See Appendix C for calculations).

Chapter Summary

The analytical methods outlined in this chapter were chosen to accurately describe debitage from the LeDx-42 site and raw materials from the Mingo and Amadjuak Lake Districts of southern Baffin Island. Individual attribute analysis will be used to describe the macroscopic visual characteristics of the debitage and raw chert samples while petrographic and trace element analyses will be conducted to determine the number of geologically unique sources available in the region. My goal is to assess the results of these analyses to determine how many chert sources exist in the regions surrounding Mingo and Amadjuak Lakes, and which ones were being exploited by the Palaeo-Eskimos at LeDx-42. Ultimately, I aim to test the assumption that there was a change in Palaeo-Eskimo raw material selection strategies throughout the continuum by examining the diversity of toolstones that were being worked at LeDx-42 over its approximately 2400-year occupation.

Chapter 6

Analysis and Interpretations

This chapter summarizes the result of the individual attribute, petrographic, and trace element analyses conducted on raw materials from the Mingo and Amadjuak Lake Districts, and lithic debitage from the LeDx-42 site located on the interior of southern Baffin Island. These analyses were undertaken to determine the types of raw materials present in the interior region and to assess Palaeo-Eskimo patterns of lithic raw material selection in the area.

First, the results of individual attribute analysis are presented. The focus of this discussion will be on qualitative attributes (i.e. colour, quality, texture), but a brief discussion of technological attributes and reduction strategies is also included. Following this, the results and interpretations of the petrographic analysis are presented. Finally the results and interpretations of the trace element analyses are discussed.

Raw Chert Samples Analyzed

Six potential source groups were established for the locally available raw materials in the Mingo and Amadjuak Lake Districts. All of the samples contain internal

flaws and are classified as fine grained. As a result, these two attributes could not be used to discriminate source groups, so colour was used instead.

ML-1 and ML-8 are by far the most common types of chert found in the area. ML-1 is light gray (hue 10YR, 7/1), and ML-8 is light gray (hue 2.5Y, 7.2). Along with ML-6, they are the only specimens that exhibit any cortex. ML-6, ML-18, MR-1, and MR-3 are considerably less common. There is no cortex present on ML-18, MR-1, and MR-3, and all three of these potential source groups contain at least some white chert.

Debitage Samples Analyzed

The total debitage sample from the six dated units at LeDx-42 contains 6920 flakes. The Pre-Dorset component contains 15.62% (N=1081) of the total sample, the Transitional 83.9% (N=5806), and the Dorset 0.48% (N=33). The majority of these flakes were visually characterized as chert (N=6882; 99.8%), and the remaining debitage can best be classified as flakes of cortex. These “cortex flakes” match the cortex present on locally available raw materials and debitage, and are therefore assumed to derive from locally available chert nodules. They were included in the study because they display attributes which indicate that they were manually removed from a core (i.e. platform, bulb of percussion) and are thus an important part of the reduction continuum present at LeDx-42. While these “cortex flakes” were included in the study, no data were collected for their colour, quality, and texture since they did not display any discernible toolstone (i.e. they consist entirely of the external cortical rind); therefore, they are not included in the discussion of these respective attribute states.

Debitage flakes are predominantly classified as fine grained (99.75%), and the remaining 0.25% are more vitreous in texture (see Table 6.1). Almost all of these flakes (98.9%) contain internal flaws and are classified as poor quality (see Table 6.2). A total of 24 colour categories were established for the study sample (see Table 6.3). Light gray (hue 10YR; 7/1) was the most common colour (34.6%), followed by gray (hue 10YR. 6/1, 34.84%), gray (hue 5Y, 5/1, 15.85%), and light gray (hue 2.5Y, 7.2, 7.54%). Cortex occurs on 19.2% ofdebitage flakes (see Table 6.4).

Table 6.1 Frequency and distribution of raw material texture at LeDx-42

Texture	Temporal Period			Total
	Pre-Dorset	Transitional	Dorset	
1	2 0.2%	15 0.3%	0 0%	17 0.2%
2	1066 98.6%	5766 99.3%	33 100%	6865 99.2%
3	0 0%	0 0%	0 0%	0 0%
4	0 0%	0 0%	0 0%	0 0%
n/a	13 1.2%	25 0.4%	0 0%	38 0.5%
Total	1081 100%	5806 100%	33 100%	6920 100%

Table 6.2 Frequency and distribution of raw material quality at LeDx-42

Quality	Temporal Period			Total
	Pre-Dorset	Transitional	Dorset	
0	11 1.0%	65 1.1%	0 0%	76 1.1%
1	1057 97.8%	5716 98.4%	33 100%	6806 98.4%
n/a	13 1.2%	25 0.4%	0 0%	38 0.5%
Total	1081 100%	5806 100%	33 100%	6920 100%

Table 6.3 Frequency distribution of debitage source groups at LeDx-42.

Colour	Temporal Period			Total
	Pre-Dorset	Transitional	Dorset	
S1	312 29.49%	2117 36.62%	17 51.52%	2449 35.59%
S2	225 21.07%	863 14.93%	3 9.09%	1091 15.85%
S3	146 13.67%	370 6.40%	3 9.09%	519 7.54%
S4	7 0.66%	62 1.07%	0 0.00%	69 1.00%
S5	5 0.47%	57 0.99%	0 0.00%	62 0.90%
S6	27 2.53%	15 0.26%	0 0.00%	42 0.61%
S7	2 0.19%	24 0.42%	0 0.00%	26 0.38%
S8	1 0.09%	5 0.09%	0 0.00%	6 0.09%
S9	0 0.00%	4 0.07%	0 0.00%	4 0.06%
S10	1 0.09%	0 0.00%	0 0.00%	1 0.01%
S11	2 0.19%	4 0.07%	0 0.00%	6 0.09%
S12	289 27.06%	2101 36.34%	8 24.24%	2398 34.84%
S13	0 0.00%	27 0.47%	0 0.00%	27 0.39%
S14	0 0.00%	6 0.10%	0 0.00%	6 0.09%
S15	0 0.00%	9 0.16%	0 0.00%	9 0.13%
S16	18 1.69%	21 0.36%	0 0.00%	39 0.57%
S17	0 0.00%	8 0.14%	0 0.00%	8 0.12%
S18	15 1.40%	54 0.93%	2 6.06%	71 1.03%
S19	1 0.09%	4 0.07%	0 0.00%	5 0.07%
S20	5 0.47%	19 0.33%	0 0.00%	24 0.35%
S21	4 0.37%	0 0.00%	0 0.00%	4 0.06%
S22	1 0.09%	8 0.14%	0 0.00%	9 0.13%
S23	1 0.09%	0 0.00%	0 0.00%	1 0.01%
S24	3 0.28%	3 0.05%	0 0.00%	6 0.09%
Total	1068 100.00%	5781 100.00%	33 100.00%	6882 100.00%

Table 6.4 Frequency and distribution of raw material cortex at LeDx-42

Cortex	Temporal Period			Total
	Pre-Dorset	Transitional	Dorset	
0 (absent)	827 76.5%	4748 81.8%	14 42.4%	5589 80.8%
1 (1-49%)	157 14.5%	627 10.8%	15 45.5%	799 11.5%
2 (50-99%)	54 5.0%	320 5.5%	4 12.1%	378 5.5%
3 (100%)	13 1.2%	25 0.4%	0 0%	38 0.5%
4 (platform)	30 2.8%	86 1.5%	0 0%	116 1.7%
Total	1081 100%	5806 100%	33 100%	6920 100%

S1, S12, S2, S3

S1 is the largest source group comprising 35.59% (N=2449) of the total sample. The chert in this groups is fine grained and of poor quality. Flakes are light gray (hue 10YR; 7/1), and a small number (3.71%; N=91) are mottled with gray (hue 2.5Y, 7.2). Only 15.5% (N=380) of the flakes in this group exhibit any cortex (see Table 6.5). While these flakes were not size-graded (see Ahler 1989a/b), they are highly variable in size from very large to very small; thus, suggesting that several different stages of the reduction continuum are present (i.e. early, middle, and late).

S12 is the second largest debitage category. It contains 34.84% (N=2389) of the total sample. The chert is fine grained and 99.5% of flakes contain internal flaws. Most flakes are a homogenous gray (hue 10YR, 6/1), but 4.1% (N=99) of these are mottled with gray (hue 5Y, 5/1). Only, 18.3% (N=439) of flakes exhibit cortex cover.

Table 6.5 Frequency distribution of cortex cover at LeDx-42.

Cortex	Cortex Cover				Total Cortex
	0%	1-49%	50-99%	Platform	
S1	2069 84.5%	242 9.9%	102 4.2%	36 1.4%	380 15.5%
S2	894 81.9%	129 11.8%	46 4.2%	22 2.0%	197 18.1%
S3	356 68.6%	87 14.5%	65 10.9%	11 1.8%	163 27.2%
S4	69 100%	0 0%	0 0%	0 0%	0 0%
S5	62 100%	0 0%	0 0%	0 0%	0 0%
S6	18 42.9%	11 26.2%	12 28.6%	1 2.4%	24 57.1%
S7	24 92.3%	1 3.8%	1 3.8%	0 0%	2 7.6%
S8	5 83.3%	1 16.6%	0 0%	0 0%	1 16.6%
S9	4 100%	0 0%	0 0%	0 0%	0 0%
S10	1 100%	0 0%	0 0%	0 0%	0 0%
S11	6 100%	0 0%	0 0%	0 0%	0 0%
S12	1959 81.7%	1276 1.5%	121 5.0%	42 1.8%	439 18.3%
S13	22 81.5%	5 18.5%	0 0%	0 0%	5 18.5%
S14	6 100%	0 0%	0 0%	0 0%	0 0%
S15	7 77.8%	22 2.2%	0 0%	0 0%	2 22.2%
S16	11 28.2%	16 41.0%	10 25.6%	2 5.1%	27 71.7%
S17	8 100%	0 0%	0 0%	0 0%	0 0%
S18	38 53.5%	114 9.7%	18 25.4%	1 1.4%	33 46.5%
S19	3 60.0%	1 20.0%	0 0%	1 20.0%	41 0.0%
S20	22 91.7%	2 8.3%	0 0%	0 0%	2 8.3%
S21	2 50.0%	2 50.0%	0 0%	0 0%	2 50.0%
S22	5 55.6%	2 22.2%	2 22.2%	0 0%	4 44.4%
S23	1 100%	0 0%	0 0%	0 0%	0 0%
S24	5 83.3%	1 16.7%	0 0%	0 0%	1 16.7%

S2 comprises 15.85% (N=1091) of the total sample. The chert is fine grained and 98.8% of flakes contain internal flaws. Most flakes are homogenous gray (hue 5Y, 5/1), with some mottled light gray (2.5Y, 7/2), and 18.1% (N=197) of flakes exhibit cortex cover. S3 comprises 7.54% (N=519) of the total lithic sample. The chert is fine grained and all flakes contain internal flaws. Flakes are light gray (hue 2.5Y, 7/2), and some are mottled with light brownish gray (hue 10YR, 1.7%; N=10), and 27.2% (N=163) of these flakes exhibit cortex.

S4, S5

The two white cherts, S4 and S5, are visually very striking and relatively abundant compared to the remaining categories. S4 contains 1% (N=69) of the total debitage sample. The chert is fine grained and 69.6% of the flakes contain internal flaws, many of which are clear quartz. Most flakes are white (gley, 8/) with a dark reddish gray tinge (hue 2.5YR, 5/1), however two of the flakes contain small amounts of gray (hue 2.5Y, 7/2). No cortex is present on any of the flakes and all are small suggesting they were removed during late stage reduction. S5 is the other white source group, and it contains 0.9% (N=62) of the total lithic assemblage. Most flakes are white (gley, 8/), but one flake is mottled with the dark reddish gray tinged white present in S4, and another is mottled with dark reddish gray tinged white and gray (hue 10YR, 6/1, i.e. the primary colour of S12). Once again, there is no cortex on any of the samples and all flakes are small suggesting they were detached from larger objective pieces that were brought to the site in an advanced state of reduction or that they derived from a bedrock outcrop, not a small nodule.

S6, S16, S20, S21

S6, S16, S20, and S21 are the only remaining debitage categories that contain any medium or large flakes more commonly associated with early and middle stage reduction. All of these cherts are fine grained and every flake contains internal flaws. S6 is classified as light olive brown (hue 2.5Y, 5/3), and cortex is present on 57.1% (N=24) of flakes. The colour of S16 is grayish brown (hue 2.5Y, 5/2), cortex is present on 71.7% (N=27) of flakes, and the full spectrum of flake sizes appears to be present in this category group. The colours of S20 are mottled white (gley, N8) and light gray (hue 7.5YR, 7/1), and cortex is present on 8.3% (N=2) of flakes. S21 is light gray (hue 2.5Y, 7/1), and one flake is mottled with white (gley, N8/). Cortex is present on 50% of flakes (N=2), and there are no small flakes present in this debitage category, only medium and large. This suggests that the flakes from these debitage categories derive from locally available nodules of chert.

S11, S15, S17

S11, S15, and S17 are the only three cherts with vitreous textures. Additionally, the flake sizes of these materials are very small. S11 (0.1%; N=6) is a dark gray (hue 5Y, 4/1) and white (hue 5Y, 8/1) banded chert. Only 66.7% (N=4) of flakes contain internal flaws and cortex is entirely absent. S15 (0.13%; N=9) is light gray (gley N6), and all flakes are classified as poor quality. Cortex is present on 22.2% (N=2) of flakes. S17 (0.18%; N=8) is a black (hue 5Y, 2.5/1) and gray (hue 2.5Y, 5/1) banded chert. Only 50% (N=4) of flakes contain internal flaws and there is no cortex present in the group. The small size and minimal amount of cortex present on these flakes suggests that they

likely derive from late stage reduction, and were detached from a curated formal tool brought to the site in its finished form. The remaining debitage categories (S7, S8, S9, S10, S13, S14, S18, S19, S22, S23, S24) are summarized in Table 6.6. These groups are very small and are primarily composed of small, fine grained flakes with little cortex.

Table 6.6 Summary of the remaining source groups including the colour and texture of raw materials, and the number of flakes with internal flaws (quality).

Source Group	Colour	Texture	Internal Flaws	
			Present	Absent
S7	Swirled reddish gray (hue 10R, 5/1) and light brownish gray (hue 2.5Y, 6/2)	Fine grained	25 96.2%	1 3.8%
S8	Banded gray (hue 5Y, 5/1), light gray (hue 2.5Y, 7/2), and gray (hue 10YR, 6/1)	Fine grained	5 83.3%	1 16.7%
S9	Dark gray (hue 2.5Y, 4/1) and grayish brown (hue 2.5Y, 5/2)	Fine grained	4 100%	0 0%
S10	Yellowish brown (hue 10YR, 5/4)	Fine grained	1 100%	0 0%
S13	Dark gray (hue 5YR, 4/1)	Fine grained	26 96.3%	1 3.7%
S14	White (hue 5Y, 8/1) and gray (hue 5Y, 5/1)	Fine grained	6 100%	0 0%
S18	Light yellowish brown (hue 2.5Y, 6/3)	Fine grained	71 100%	0 0%
S19	White (gley, N8), gray (hue 5Y, 5/1) and light yellowish brown (hue 2.5Y, 6/3) (was 25)	Fine grained	5 100%	0 0%
S22	Pale Yellow (2.5Y, 7/4)	Fine grained	9 100%	0 0%
S23	Pinkish Gray (hue 7.5Y, 7/2)	Fine grained	0 0%	1 100%
S24	Black (hue 5Y, 2.5/1)	Fine grained	5 83.3%	1 16.7%

Individual Attribute Analysis: Interpretations

Based on my visual assessment of the debitage, it appears that the Palaeo-Eskimos used 24 distinct raw material types throughout their 2400-year occupation of LeDx-42. Six of these flake categories are visually identical to the six potential source groups established for the locally available raw materials. Specifically, the appearance of ML-1 matches that of S1; ML-6 matches S10; ML-8 matches S3; ML-18 matches S4; MR-1 matches S20; and MR-3 matches S19. Based on the indistinguishable appearances of these potential source groups and the debitage categories, it would appear that they are one and the same. This means that debitage from S1, S3, S4, S10, S19, and S20, based on solely on visual characteristics, was most likely produced from these locally derived lithic raw materials.

Debitage from S1, S2, S3, and S12 have been categorized into four distinct debitage categories; however, it is possible that they all derive from the same source since each one is linked to the other by several shared colours. For example, the primary colour of S3 is the same as the secondary colour of S2 (light gray: hue 2.5Y, 7/2), the primary colour of S2 matches the secondary colour of S12 (gray: hue 5Y, 5/1), and the primary colour of S12 matches the secondary colour of S1 (gray: hue 10YR, 6/1). These relationships are more clearly illustrated in Figure 6.1. The interconnectedness of these shared colour categories may mean that all of these materials derive from a single, highly variable nodule, and that through the process of reduction, the colours it contained became increasingly separated from one another giving the false impression that multiple nodules were being worked rather than one that was internally variable (see Malyk-Selivanova *et al* 1998).

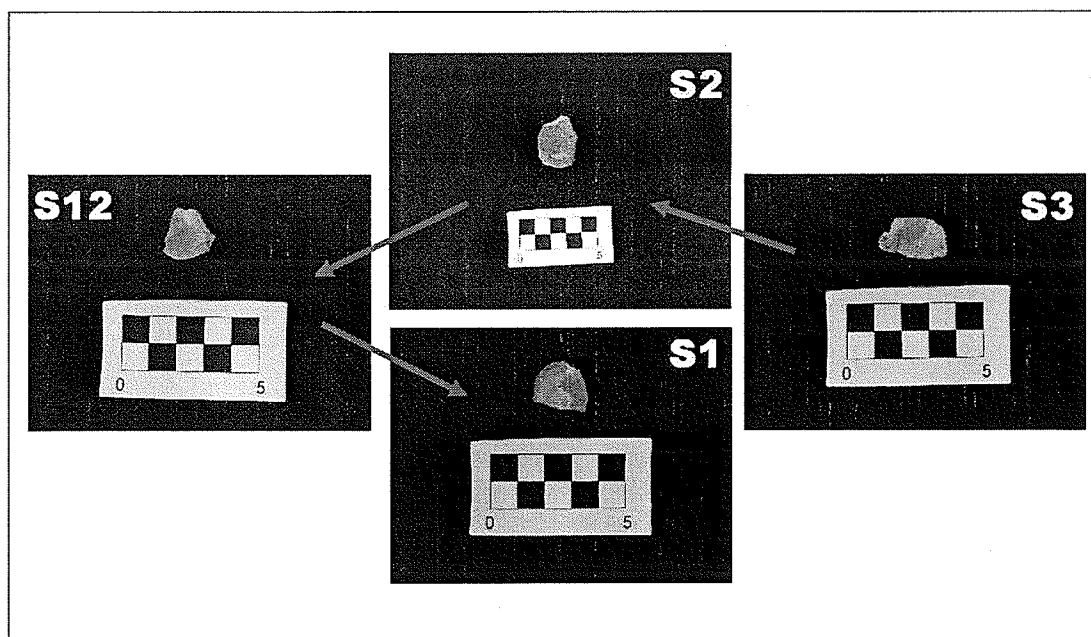


Figure 6.1 Diagram representing the possible interconnectedness of the S1, S2, S3, and S12 source groups based of shared colour categories.

Three other debitage categories are also linked by shared colour attributes. The primary colour of S4 is the same as the secondary colour of S5 (white: gley, 8/. tinged dark reddish gray: hue 2.5YR, 5/1) while the primary colour of S5 is the same as the secondary colour is S4 (white: gley, 8/). Additionally, the primary colour of S12 is the same as the tertiary colour of S5 (gray hue 10YR, 6/1) (Figure 6.2). Unlike the other associated debitage categories, the colours of this collective are highly divergent, and it is unlikely that an archaeologist performing a visual analysis would ever group them together without mottled samples. However, it is still possible that all of these raw materials may derive from a single source.

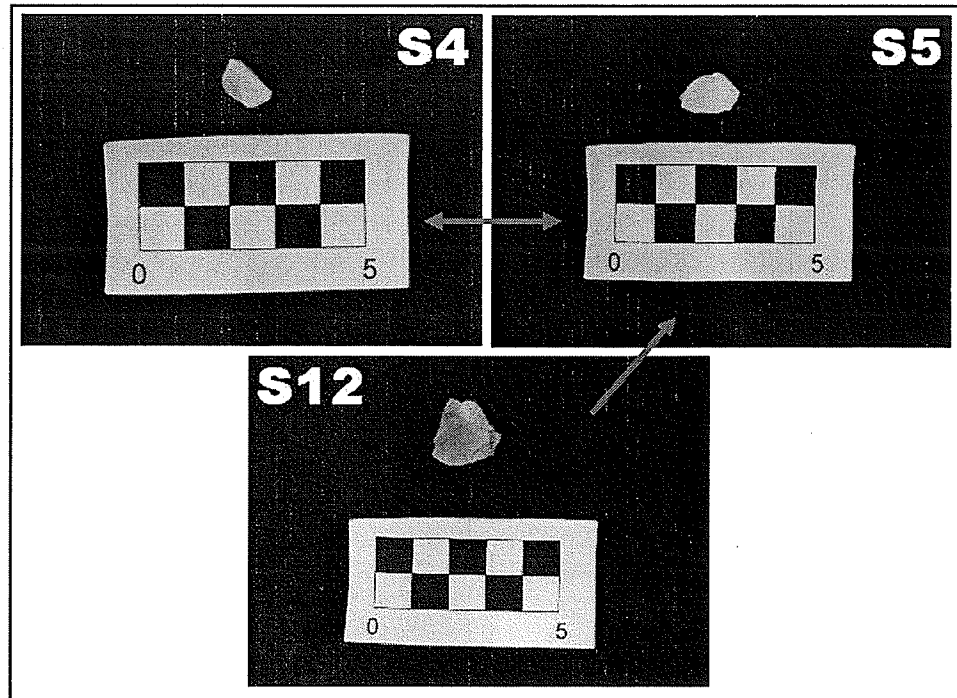


Figure 6.2 Diagram representing the possible interconnectedness of the S4, S5, and S12 source groups based of shared colour categories.

Cortex should be most abundant in locally available raw materials and scarce in those considered to be non-local and/or exotic. This pattern occurs because individuals transporting raw materials long distances will economize the total amount of stone being carried (see Beck *et al* 2002). This is done by discarding any unnecessary parts of the raw materiel (i.e. the cortex) and maximizing the total amount of usable stone in a single package (Bradbury and Franklin 2000). Using IAA, I have established that S1, S3, S4, S10, S19, and S20 are available locally, and by extension, so are S2, S5, and S12. There is no cortex present on S4 and S5, but this is not surprising as their ML-18 counterpart exhibits no cortex either. The small amounts of cortex in S19 and S20 may also be attributed to a lack of cortex on their parent raw materials, MR-3 and MR-1. Cortex is likely absent on the one flake present in S10 because it was detached during late stage

reduction. This inference is confirmed by the flake's small size, 2 dorsal scars, and intact platform.

On average, 19.8% of flakes from the four largest source groups, S1, S2, S3, and S12, exhibit cortex cover. Because the full range of the reduction may be present in these source groups, the amount of cortex in the overall assemblage seems small. However, considering cortex tends to be absent after the first of many stages of reduction and smaller flakes quickly outnumber large ones as reduction proceeds, 19.8% cortex is still significant. With this in mind, S6, S12, S13, S16, S18, S21, and S22 are seven source groups with comparatively high amounts of cortex. The high proportions in these three groups suggest that they may derive from locally available chert nodules.

The non-local and/or exotic raw materials in a debitage assemblage generally account for the highest quality raw materials. There are six source groups in the present assemblage that fit this criterion: S7, S9, S11, S14, S17, and S23. The quality of these raw materials is very high, and all have been classified as fine grained except for S11, and S17 which are classified as vitreous.

Pre-Dorset

The Pre-Dorset debitage assemblage contains 15.5% (N=1081) of the total study sample. The majority of this Pre-Dorset debitage assemblage is classified as fine grained (99.81%), with the remaining 0.19% classified as vitreous raw materials. Almost all flakes contain internal flaws (98.97%) and are of poor quality. Cortex occurs on 23.5% (N=254) of the debitage assemblage. Nineteen of the twenty-four debitage categories are present in the Pre-Dorset assemblage, and overall, the proportions of these raw materials

are similar to the proportions in the overall study sample; specifically, S1, S2, S3, and S12 are still the largest debitage categories and comprise 89.91% (N=972) of the total, while each of the remaining debitage categories accounts for 2.5% or less of the total lithic assemblage. Additionally, there are three debitage categories exclusive to this temporal period: S10, S21, and S23. S10 comprises a single very small fine grained flake with internal flaws and no cortex. S23 also comprises a single fine grained flake that exhibits no internal flaws or cortex. Four flakes are present in S21, and they are fine grained, poor quality, and two exhibit cortex.

Transitional

The Transitional assemblage contains 84% (N=5806) of the total study sample. The majority of flakes are classified as fine grained (99.7%), with the remaining 0.26% being attributed vitreous raw materials. Almost all of the flakes contain internal flaws and are classified as poor quality. Cortex occurs on 18.2% (N=1058) of the study sample. Twenty-one of the 24 debitage categories are present in the Pre-Dorset assemblage, and overall, the proportions of these raw materials are similar to those present in the overall sample. S1, S2, S3, and S12 are still the largest debitage categories comprising 93.89% (N=5451) of the assemblage, while the remaining categories account for 1.1% or less. Additionally, there are five debitage categories exclusive to this temporal period: S9, S13, S14, S15, and S17. The debitage present in S9 and S14 is fine grained, of poor quality, and exhibits no cortex. Most of the debitage in S13 are fine grained (96.3%; N=26), but one flake is classified as vitreous, and cortex is present on 18.5% of flakes. Flakes in S15 and S17 are classified as vitreous. All of the flakes in

S15 contain internal flaws, and cortex is present on 22.2% (N=2) of them. Half of the debitage in S17 contains internal flaws and none of them exhibit cortex.

Dorset

The Dorset assemblage is very small containing only 0.48% (N=33) of the total study sample. The entire assemblage is classified as fine grained, every flake contains internal flaws, and cortex occurs on 57.6% (N=19) of flakes. Only five of the twenty-four debitage categories are present in the Dorset assemblage. S1, S2, S3, and S12 are still the largest source comprising 93.34% (N=31) of the total assemblage. The remaining group, S18, makes up only 6.06% (N=2) of the total assemblage.

Interpretations

The Palaeo-Eskimos appear to have relied most heavily on the same four locally available raw materials throughout the continuum: S1, S2, S3, and S12 (see Table 6.7). Additionally, it appears as though the Pre-Dorset and Transitional occupants of LeDx-42 were importing high quality, fine grained and vitreous raw materials to the site, some of which are unique to their respective temporal periods. This does not mean that patterns of raw material selection changed between the Pre-Dorset and Transitional periods, because they were still selecting the same proportions of local and non-local and/or exotic raw materials. However, it does suggest that their mobility patterns may have changed granting them different access to raw materials, or their exchange networks may have shifted.

Table 6.7 Frequency and distribution of the S1, S2, S3, and S12 debitage categories throughout the Palaeo-Eskimo culture continuum at LeDx-42

	Temporal Period			
Colour	Pre-Dorset	Transitional	Dorset	Total
S1	29.49%	36.62%	51.52%	35.59%
S2	21.07%	14.93%	9.09%	15.85%
S3	13.67%	6.40%	9.09%	7.54%
S12	27.06%	36.34%	24.24%	34.84%
Total	91.29%	94.27%	93.94%	93.82%

The absence of any exotic raw materials in the Dorset assemblage is most likely due to the very small sample size. S1, S2, S3, and S12 remain the largest and most popular debitage categories throughout the entire continuum, and the proportions of the raw materials selected appear to have changed very little over time. This strongly suggests that the Dorset relied on the same locally available raw materials as the rest of their Palaeo-Eskimo counterparts. It is also possible the Dorset were exploiting non-local and/or exotic raw materials in the same proportions as well, but because these better quality toolstones are comparatively rare in the Palaeo-Eskimo lithic assemblage at LeDx-42, they do not appear in the small Dorset assemblage. Overall, from these data, it seems apparent that there was little or no change in Palaeo-Eskimo raw material selection strategies at LeDx-42. Throughout the 2400-year Palaeo-Eskimo occupation of the site, toolmakers appear to have consistently exploited the same locally available lithic raw materials and in the same overall frequencies.

Debitage Source Groups: Technological Attributes

The attribute states of the Pre-Dorset and Transitional flakes sampled for destructive analysis (see Appendix C) are presented here. These technological attributes

have the power to lend valuable insight into the types of strategies used by the Palaeo-Eskimos during these two temporal periods to reduce lithic raw materials. The wide range of raw materials sampled for destructive analysis will allow me to observe changes in reduction strategies according to the types of raw materials being reduced (i.e. local vs. non-local). Additionally, by observing the reduction patterns practiced in each of these temporal periods, I will be able to evaluate if reduction strategies changed over time. However, it should be noted that these samples were not selected specifically to describe Palaeo-Eskimo technological strategies. Rather, each sample was selected for thin-section analysis based on their unique physical appearance. In addition to selecting flakes that visually characterized each source group, large flakes were preferentially selected from each group to facilitate thin section analysis. Therefore, the technological strategies presented in this section will be biased towards those associated with larger flake sizes – the flakes will most likely represent the earliest stage of reduction present on-site for their respective debitage categories.

Platform type, dorsal scar count, cortical cover, size and weight were all used to determine the stage of reduction for each detached flake. Because technological attributes were not recorded for the entire LeDx-42 study sample, only very general classifications of “early” or “late” are made in this analysis. The flakes from the largest debitage categories, S1, S3, and S12 were all attributed to early stage reduction.

Although each had multifaceted platforms and S12 has a high dorsal scar count, the presence of cortex, and the large size of each flake indicates that they were detached during early stage reduction. S2 and S22 were classified as shatter because a single interior surface could not be identified (see Sullivan and Rozen 1985). Early stage flakes

are also attributed to S4, S5a, S5b, S6, S16, S18, and S21 (see Table 6.8 for flake attributes). Unsurprisingly, the debitage categories previously classified as local basically match the early stage flakes present in these samples. This suggests that these raw materials were being collected and reduced on-site. At the other end of the spectrum are the late stage flakes: S8, S11, S13, S15, S20, and S24. The small size, absence (or near absence in the case of S15) of cortex, and the presence of two or more dorsal scars on each flake indicate that they were detached during late stage reduction (see Table 6.8 for attributes), and most likely brought to the site in an advanced state (i.e. they are from curated tools).

Interpretations

Eight of the flakes selected for destructive analysis were from the Pre-Dorset lithic assemblage (S3, S6, S11, S12, S16, S20, S21, S22), and ten from the Transitional (S1, S2, S4, S5a, S5b, S8, S13, S15, S18, S24). As noted already, no flakes were sampled those units with Dorset period dates because flake sizes were too small for thin section analysis. Both the Pre-Dorset and Transitional groups contain early and late stage reduction flakes. Therefore, reduction strategies during both temporal periods do not appear to have changed. Locally available raw materials were being collected and reduced on site as evidenced by the presence of early stage flakes for these materials, while non-local and/or exotic raw materials appear to have only been introduced into the local reduction continuum as finished or nearly finished stone tools.

Table 6.8 Summary of the technological attributes used to determine the reduction stage of debitage selected for destructive analysis.

	Cortical Cover	Platform Type	Dorsal Scar Count	Size	Weight (g)
S1	1-49%	Multiple facets with crushing	1	>31 mm	1.7
S2	1-49%	Indeterminate	0	>31 mm	15.6
S3	50-99%	Multiple facets with cortex	2	>31 mm	2.2
S4	Absent	Single facet	2	20-25 mm	0.2
S5a	Absent	Single facet	1	20-25 mm	0.5
S5b	Absent	Indeterminate	2	26-30 mm	0.5
S6	1-49%	Single facet with cortex	1	>31 mm	5.5
S8	Absent	Multiple facets with crushing	3	20-25 mm	0.3
S11	Absent	Indeterminate	2	20-25 mm	0.2
S12	1-49%	Multiple facets with crushing	4	>31 mm	1.7
S13	Absent	Single facet	2	20-25 mm	0.4
S15	1-49%	Multiple facets	2	20-25 mm	0.5
S16	1-49%	Single facet with cortex	4	>31 mm	3.3
S18	1-49%	Multiple facets with cortex	1	20-25 mm	0.7
S20	Absent	Multiple facets	4	>31 mm	2.8
S21	Absent	Multiple facets with crushing	2	>31 mm	2.9
S22	1-49%	Indeterminate	0	20-25 mm	0.5
S24	Absent	Single facet	4	20-25 mm	0.1

Microscopic Analysis

There appears to be two types of chert present in the LeDx-42 lithic assemblage: white chert and tan chert. Under the microscope, the white chert appears to be free of any impurities, while the tan chert contains many impurities, the most common of which is unaltered calcite (CaCO_3), which appears as small brownish grains.

Raw Materials

Six potential raw material source groups were analyzed under the microscope: ML-1, ML-6, ML-8, ML-18, MR-1, and MR-3 (See Appendix D for images). ML-1 and ML-8 represent two of the three homogenous pieces of tan chert. Under the microscope, a dark tan is concentrated in the centre of the sample, and a very light tan surrounds it. Patches of unaltered calcite are the only inclusions present, and both types of stone appear identical. Within the third homogeneous tan chert sample, ML-6, patches of calcite are found throughout and a single large brachiopod fragment (a mollusc-like marine animal of the Brachiopoda phylum) is present near its centre. Also identified in the centre of the sample is a linear dispersion of an indeterminate organic material.

Among the remaining three samples, ML-18 consists of homogenous white chert without any trace of impurity. MR-1 and MR-3 are composed of both white and tan chert. MR-1 displays a high degree of internal diversity: two small areas of tan chert are present in the sample which contains patches of unaltered calcite, brachiopod shells, and quartz inclusions. Just below one of these areas, a small vein of quartz was identified and on the other side, is white chert which encompasses about 80% of the sample. MR-3 also contains a significant amount of internal diversity. Tan chert accounts for about 40% of the sample while patches of unaltered calcite and mollusc and brachiopod shell are found throughout. Veins and patches of clear quartz are also present throughout the sample, both in the tan chert and white chert. The remaining 60% of the sample is attributed to white chert.

Debitage

Eighteen flakes from the 17debitage categories were examined under the microscope: S1, S2, S3, S4, S5a, S5b, S6, S8, S11, S12, S13, S15, S16, S18, S20, S21, S22, and S24 (see Appendix D for images). S6, S8, S13, S15, S16, and S24 all appear very similar; they are all homogenous tan chert and contain patches of calcite. Except for the presence of mollusc shells in S13 and S15, and small dark patch of indeterminate organic matter in S15 and 16, the six samples are identical. S1 and S3 are identical to one another as well. Both are homogenous tan chert with patches of calcite throughout. Half of each sample contains brachiopod shells, and the other half has an increased presence of calcite and a small number of quartz inclusions. S18 and S22 are also very similar to each other. Both samples are homogenous tan chert, and under the microscope, two shades of chert are visible; a darker tan in the middle and a very light, almost clear tan around the periphery. Unaltered calcite is present in both samples, and a few quartz inclusions are present in S22. The final pairing of similar chert samples includes S2 and S12. Both samples appear as typical tan cherts with patches of unaltered calcite throughout; however, there is a single quartz inclusion is present in S12. Near the centre of S2 and S12 there is a circular area that appears black under the microscope, but to the naked eye is white. The composition of these areas has not been determined, but they do link these two samples together. S11 is the final sample of pure tan chert. The sample contains a significant patch of indeterminate organic matter, and unlike the rest of the samples, there is no calcite present.

Two homogenous white chert samples were examined: S4, and S5a. Under the microscope both are typical white cherts and contain no internal inclusions. Sample S5b

was originally classified to its source group because it contained 95% white chert. However, very small amounts of the tinged chert present in S4 and the primary colour of S12 are also present in this sample. There are three areas of tan chert present in the specimen, yet only one of them is visible to the naked eye. Within each of these areas calcite is the only impurity. The rest of the sample appears to be white chert with small quartz inclusions throughout. To the naked eye, cross-sections of S20 and S21 appear very complicated. However, when placed under the microscope they are simplified. Each contains a single area of tan chert with patches of calcite, and a single area of pure white chert. While S20 is composed of about 80% white chert, and S21 is around 90% tan chert, the two samples appear identical under the microscope.

Interpretations

Petrographic analysis considerably reduces the number of potential source groups. Based on these analyses, there are four types of raw materials available locally in the study area: a combined grouping of ML-1 and ML-8; MR-1 and MR-3; ML-6; and ML-18. Similarly, the total number of potential source groups within the debitage assemblage has been reduced to eight: a combined grouping of S6, S8, S13, S15, S16, and S24; S1 and S3; S18 and S22; S2 and S12; S4 and S5a, S20 and S21, S5b, and S11. Additionally, two of the potential raw material debitage categories can be linked to three of the debitage source groups. The appearance of ML-1 and ML-8 matched that of S18 and S22; MR-1 and MR-3 match S20 and S21; and ML-18 match S4 and S5b.

Geochemical Analysis

The bulk trace element concentrations of the six raw material samples were measured using ICP-MS analysis. By observing the elemental concentrations of these samples, it was determined that the concentration of ^{27}Al plotted against a ratio of $^{69}\text{Ga}/^{92}\text{Zr}$ best determined individual source groups. Further, the six raw samples tested cluster into a single group, suggesting that they all derive from a single geological source.

Debitage from the 17 established debitage categories were measured with SIMS using the same ^{27}Al vs. $^{69}\text{Ga}/^{92}\text{Zr}$ values. When debitage samples contained internal diversity, each distinct location was sampled in order to capture the full range of variability present in each specimen. These values were then averaged to render them comparable with the raw material source groups. Data collected for the debitage source groups are presented in Figure 6.3.

The results indicate that the 17 debitage categories established in IAA and petrographic analysis actually cluster into four discrete groups. The first cluster (labeled 1 in Figure 6.3) includes eleven source groups: S2, S3, S5a, S6, S11, S13, S15, S16, S20, S21, and S24. A range of colours and textures are present in this cluster. The texture of S11 and S15 are vitreous, while the remaining samples are fine grained, and the assortment of colours includes: white and tan; mottled white and tan, and banded grey and black. The second cluster (labeled 2 in Figure 6.3) includes five source groups: S4, S5b, S8, S18, and S22. Once again, there is a range of colours and textures present in this cluster, and all are classified as fine grained. Overall, the ^{27}Al values of this cluster are similar to those present in the cluster 1, but the $^{69}\text{Ga}/^{92}\text{Zr}$ ratio is noticeably higher. The final two defined source areas contain a single flake each. The first of these, S12

(labeled 3 in Figure 6.3), has a similar $^{69}\text{Ga}/^{92}\text{Zr}$ ratio as the first cluster, but its ^{27}Al concentration is significantly higher. The final source group contains S1 (labeled 4 in Figure 6.3). The $^{69}\text{Ga}/^{92}\text{Zr}$ ratio for this specimen is much higher than the other three, and its ^{27}Al concentration averages between those of cluster one and two, and cluster three. The differing ^{27}Al and $^{69}\text{Ga}/^{92}\text{Zr}$ values among the four clusters are most likely the result of differing depositional environments. Each environment is made unique by its distinctive temperature (Mizutani 1977; Stamatakis and Magganas 1989; Tribble *et al* 1992), pH (Fournier 1973; Hein and Yeh 1983), and collection of impurities (Isaacs 1982; Williams and Crerar 1985).

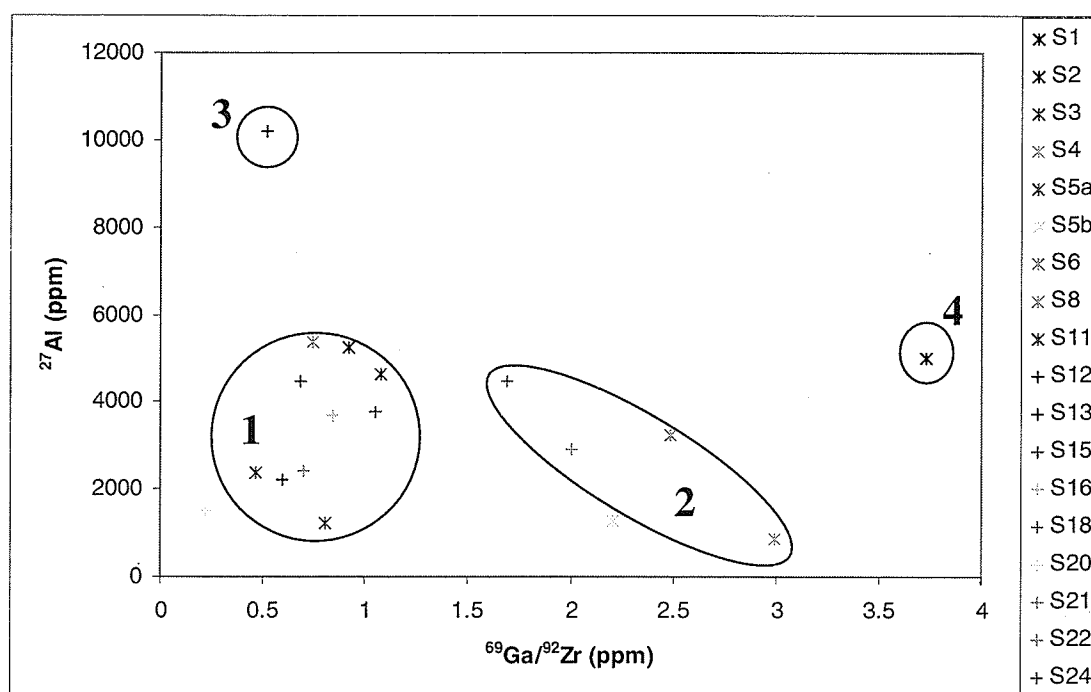


Figure 6.3 A plot using ^{27}Al vs. $^{69}\text{Ga}/^{92}\text{Zr}$ of the 17 debitage source groups analyzed using SIMS.

Interpretations

The clustering of source groups does not seem to be influenced by the colour and texture of samples. The two largest clusters contain a variety of different colours and textures that would never be paired together in traditional visual analysis. At the beginning of the chapter, using IAA, I assembled two groups of debitage and predicted each derived from a single source (see Figures 6.1 and 6.2). These predictions were based on the presence of shared colours between samples in each group. For example, in debitage sample S5b, small amounts of S4 and the primary colour of S12 are present. Therefore, I assumed that these samples all derived from the same geological source. However, SIMS data proves this prediction false. In fact, S4, S5b, and S12 are divided between three of the four SIMS determined source clusters. Even more surprising is the separation of S5a (homogenous white) and S5b into two discrete source clusters. Although they were visually characterized as members of the same source group, geochemical data reveal that this is not the case. The reason for this separation could be due to the mottling of S5b, the presence of two distinct colours in this sample may have changed the bulk chemical composition of the flake.

The second IAA derived grouping of debitage contains the four most common raw material types present in the debitage assemblage: S1, S2, S3, and S12. The samples were grouped together based on the presence of shared colours, but once again the grouping was falsified by the geochemical data and the samples are spread among three source clusters. This confirms that visual methods alone are inadequate to source raw materials from the interior of southern Baffin Island. The raw materials are far too

variable and simply cannot be accurately or reliably separated into discrete categories using IAA.

The source groupings derived from petrographic analysis are slightly more promising when compared to the geochemical data. A total of 8 debitage source groups were generated in this analysis, and six of these are composites of the potential source groups established in the visual analysis. Three of these presumed source groups (S1 and S3; S2 and S12; S4 and S5) are spurious. However, the separation of the samples into the remaining five groups are supported by the geochemical data and thus reflect actual source areas. While these results do not suggest that petrographic analysis is the best method for raw material sourcing, it does confirm that it is superior to macroscopic visual analysis.

Raw Materials: Selection Strategies

The trace element concentrations of the LeDx-42 debitage and the raw chert samples were plotted together to determine if the Palaeo-Eskimos at the site were using these local nodules and if patterns of use changed over time (see Figure 6.4).

All of the local raw materials tested with ICP-MS plot within the confines of a single cluster (labeled 1 in Figure 6.4). Through association, the debitage that falls within this cluster is classified as “local,” and the remaining three clusters are classified as non-local and/or exotic. Only about half of the raw materials predicted to be locally available using visual analysis at the beginning of this chapter actually fall within the “local raw material” source cluster while none of the debitage predicted to be non-local

and/or exotic falls within the “exotic” source clusters. Once again, visual analysis has failed to accurately source raw materials.

The two most common types of raw material present in the Palaeo-Eskimo debitage assemblage, S1 and S12, fall outside the boundaries of the “local raw material” source group. While it is possible that Palaeo-Eskimos were importing these two raw materials to LeDx-42 in large quantities, it is more likely that representative raw samples reflecting the full range of locally available raw materials were not collected from the study areas, and that the absence of these samples is skewing the data. If this is the case and S1 and S12 are considered to be locally available, then all of the non-local and/or exotic raw materials present in the Palaeo-Eskimo lithic assemblage derive from a single source (labeled 2 in Figure 6.4).

Figures 6.5 and 6.6 illustrate the correlations between the locally available raw material sources and the debitage samples analyzed from the Pre-Dorset and Transitional periods at LeDx-42. This was done to evaluate which sources were being exploited and to determine if there were any changes in the selection strategies employed over time to test the premise that Palaeo-Eskimo toolstone selectivity increased throughout the cultural continuum in favour of exotic materials over locally derived sources.

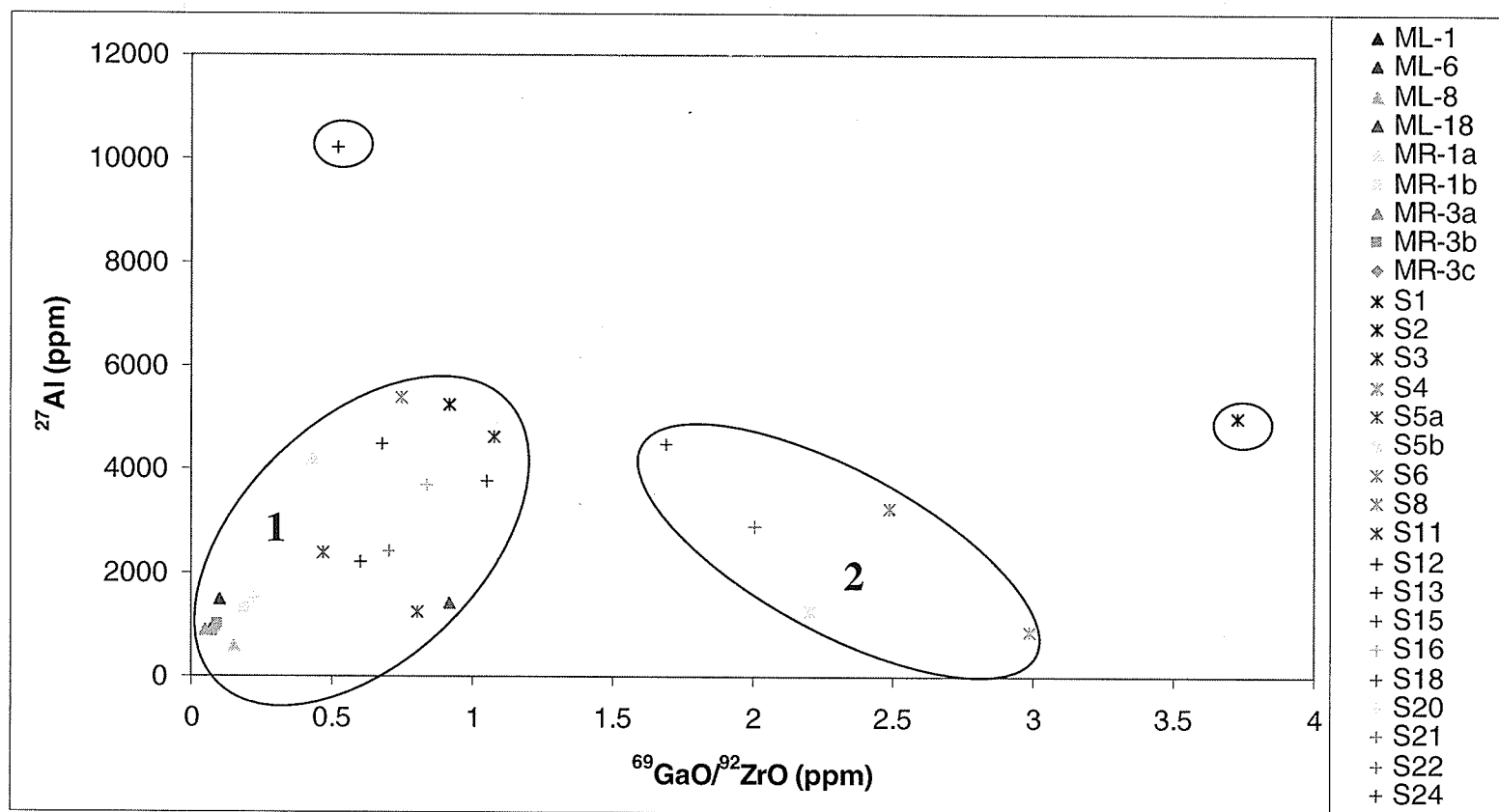


Figure 6.4 A plot using ^{27}Al vs. $^{69}\text{Ga}/^{92}\text{Zr}$ of the local raw chert material and LeDx-42 debitage.

As discussed above, eight flakes from the Pre-Dorset study sample (S3, S6, S11, S12, S16, S20, S21, S22) underwent SIMS analysis. The results of this analysis are presented in Figure 6.5. In total, the debitage clusters into three discrete groups. Six of the flakes (S3, S6, S11, S16, S20, S21) fall within the same cluster as the locally available raw cherts (labelled 1 in Figure 6.5), and are therefore “local” by association. The remaining two clusters contain only a single flake each. One of these (labelled 3 in Figure 6.5) contains S12, one of the largest debitage categories in the study sample. As discussed above, this category is has been inferentially classified as “local.” The final cluster (labelled 2 in figure 6.5) contains S22 and is classified as a non-local and/or “exotic” source group.

Ten flakes from the Transitional period were analyzed (S1, S2, S4, S5a, S5b, S8, S13, S15, S18, S24). The results of this analysis are presented in Figure 6.6. Five of the flakes (S2, S5a, S13, S15, S24) fall within the same cluster as the locally available raw cherts (labelled 1 in Figure 6.6), and are thus deemed “local.” The second cluster (labelled 4 in Figure 6.6) contains only S1. As discussed, this debitage category is most likely “local”. The final cluster, (labelled 2 in Figure 6.6) contains four of the debitage categories (S4, S5b, S8, S18) and is classified as non-local and/or “exotic”.

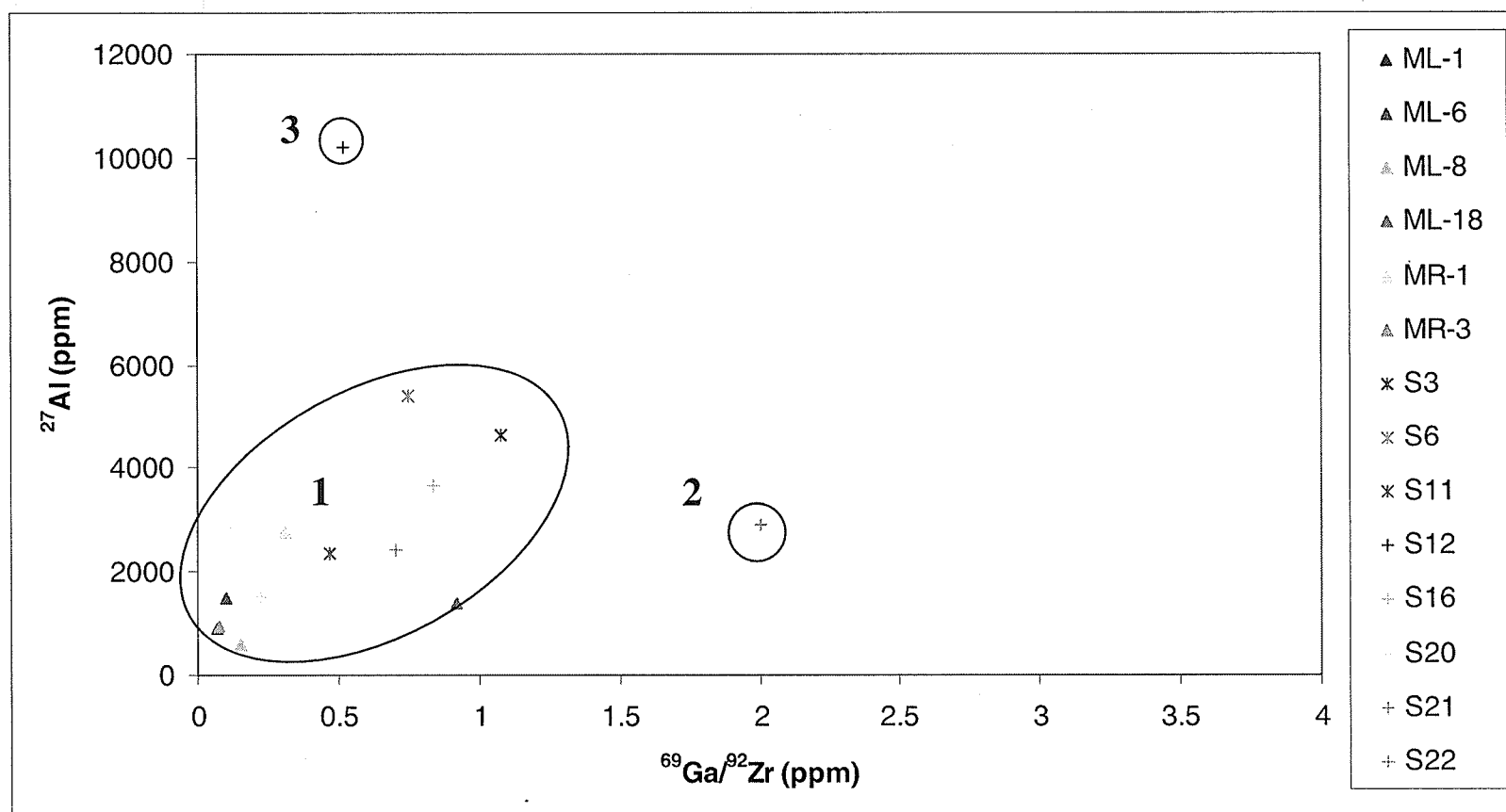


Figure 6.5 A plot using ^{27}Al vs. $^{69}\text{Ga}/^{92}\text{Zr}$ of the raw material and debitage source groups available during the Pre-Dorset occupation of LeDx-42.

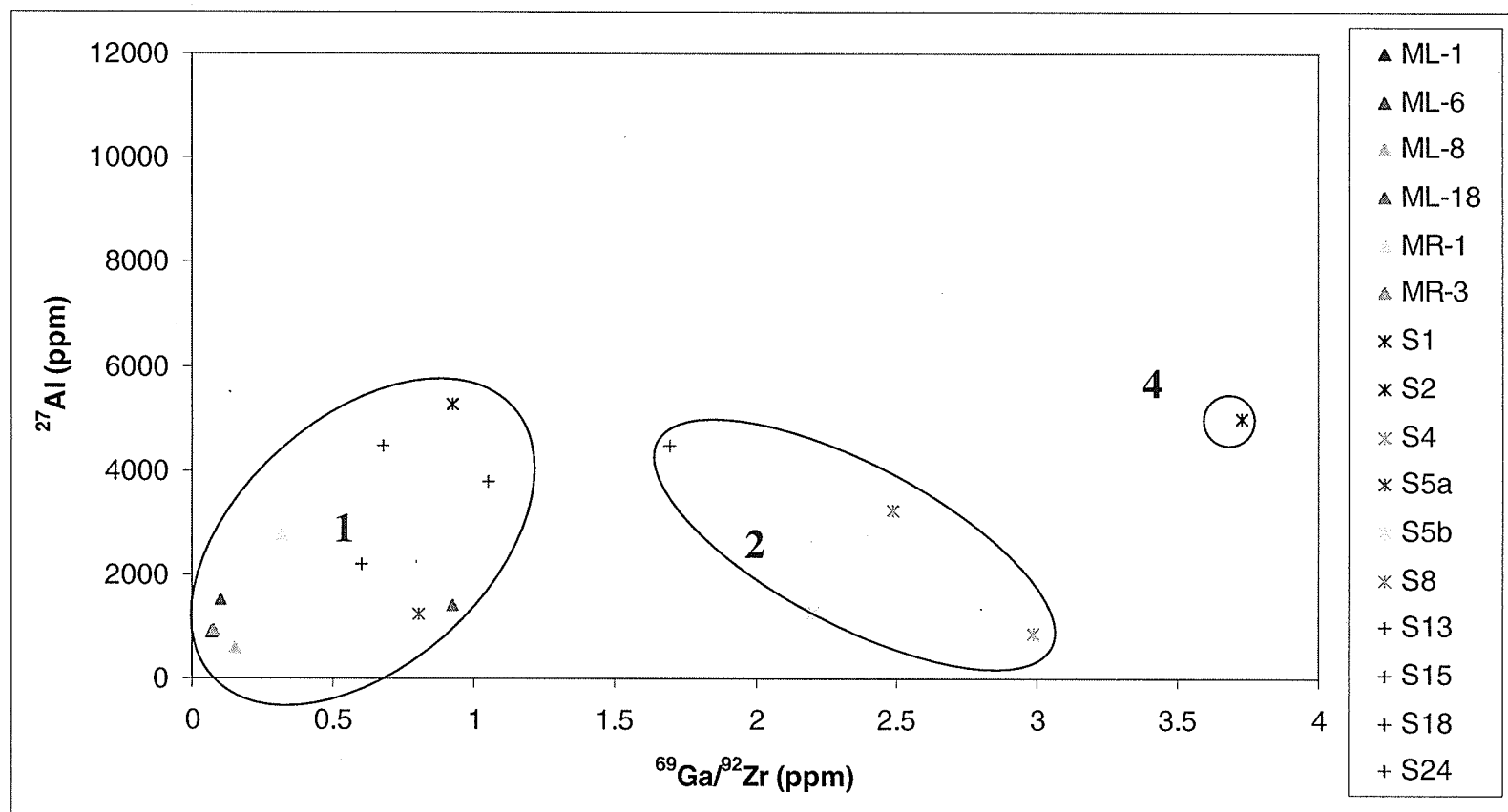


Figure 6.6 A plot using ^{27}Al vs. $^{69}\text{Ga}/^{92}\text{Zr}$ of the raw material and debitage source groups available during the Transitional occupation of LeDx-42

Interpretations

Three source clusters are represented during the Pre-Dorset and Transitional periods. Most notably, clusters 1 and 2 are both well represented indicating the consistent exploitation of local raw materials and the non-local source group. The proportionate frequencies of materials from these two clusters are also very consistent in the overall study samples from both the Pre-Dorset and Transitional periods. The debitage categories present in cluster 1 during the Pre-Dorset period comprise 18.9% of the total study sample, and during the Transition period they comprise 16.6%. In comparison, the debitage categories present in cluster 2, the non-local source group, comprise 0.1% of the Pre-Dorset study sample and 3.1% of the Transitional sample. This suggests that during these two temporal periods, the occupants of LeDx-42 relied more heavily on the locally available raw materials from cluster 1 than they did on non-local raw materials from cluster 2. While it may appear as though a slight increase in non-local raw material selection occurred between the Pre-Dorset and Transitional periods (from 0.1% to 3.1%), the change does not remotely approximate the sizeable increases noted by Nagy (1997, 2000) in her study. Rather, the increase here is modest at best and is most likely an artifact of the sampling used during excavation of the site rather than an actual shift in selection preferences over time.

The final source group exploited by the Pre-Dorset is cluster 3 (labelled 3 in Figure 5.5) and consists solely of S12. Raw material from this source group was heavily exploited and comprises 27.1% of the total Pre-Dorset study sample. However, cluster 3 is absent during the Transitional period. It is unlikely that the exploitation of this source ceased with the Pre-Dorset. In fact, based on the IAA analysis, it is clear that S12 remains

important into the Transitional period. The case is likely similar for the last of the three source groups exploited during the Transitional period. Cluster 4 (labelled 4 in Figure 6.6) consists entirely of the debitage category S1, the largest debitage category during the Transitional period comprising 36.62% of the total study sample. However, cluster 4 is absent during the Pre-Dorset period. Data from IAA suggests that S1 was an important raw material during the Dorset period. Therefore, it is unlikely that the cluster 4 source grouping was not being selected by the Pre-Dorset.

It is possible the presence/absence of these two groups (i.e. S12 and S1, respectively) from the Pre-Dorset and Transitional period is, again, an artifact of the sampling used during excavation of the site rather than an actual shift in selection preferences over time. However, it may also be attributable to the fact that either group simply did not use these other local nodules during the occupation of the site because they were not readily available or they just preferred to use other stones. In other words, the Pre-Dorset may have found a cluster of chert representing S12 in close proximity to LeDx-42 and used it intensively. Over time, nodules of this chert may have become scarce within the immediate site area. Therefore, toolmakers during the Transitional period may have had to walk a little further to find useable stone. In doing so, they may have come across nodules representing S1. This would certainly account for these observed patterns; however, until more of the site is excavated and samples tested, it will be difficult to say for certain. What does remain clear is that there was not a radical shift in the use of local cherts over time between the Pre-Dorset and Transitional periods at LeDx-42 and use of non-local and/or exotics remained negligible at best.

Raw Material Selection: An Inferential Model

It is possible to construct a more detailed model of Palaeo-Eskimo raw material selection by considering the colour categories established in IAA alongside SIMS data. The model is based on the assumption that flakes with the same attribute states (i.e. colour) derive from the same geological source. Therefore, all flakes attributed to the same colour category in IAA are assumed to originate from the same source (e.g. all white flakes categorized as S5 originate from one source, while all the gray flakes categorized as S1 belong to another), regardless of cultural affiliation (i.e. Pre-Dorset, Transitional, Dorset). So, while only a single flake from each debitage category was selected for SIMS analysis in this study, the data collected from each category is applied to all debitage from the same colour category regardless of cultural affiliation, and used to assess patterns of raw material selection at LeDx-42. The results of this analysis are presented below.

Interpretations

During the Pre-Dorset period, 15 of the 17 established source groups are present (see Figure 6.7). All four source clusters are represented, but the majority of these are found within a single cluster and are classified as local. Selection patterns are near identical during the Transitional period (see Figure 6.8). Sixteen of the 17 source groups are present in the debitage assemblage. Once again, all four source clusters are represented. Only five of the seventeen sources groups are present in the Dorset assemblage (see Figure 6.9). All of these are locally available except for S18 which is located in the non-local cluster.

As established already, there is little change in raw material selection strategies between the Pre-Dorset and Transitional occupations at LeDx-42. Only five types of raw materials were used during the Dorset period, and like the patterns identified during the Pre-Dorset and Transitional periods, four of the dominant types present in these study samples were also used by Dorset toolmakers at the site. The fifth raw material is classified as non-local and/or exotic and it accounts for proportionately the smallest frequency of toolstone used during this time. Therefore, it is possible to infer that the Dorset were also intensively exploiting locally available cherts during their occupation of LeDx-42 and that use of non-local and/or exotic toolstones was negligible. These patterns indicate a high level of consistency in toolstone selection throughout the cultural continuum in this region of southern Baffin Island.

As mentioned earlier in the chapter, the small size of the Dorset assemblage tends only to show large scale and important behaviours. Simply, small sample sizes only allow you to observe generalized behaviours enacted at the population level, but do not contain specific enough data to observe micro-scale behaviours. This is why lithic resources like S1, S2, S3, and S12 are still present within the Dorset sample – they were the most important and most commonly exploited raw materials during the Palaeo-Eskimo culture continuum. So, the presence of S18 in the Dorset lithic assemblage indicates that it was also an important lithic resource selected throughout the Palaeo-Eskimo continuum.

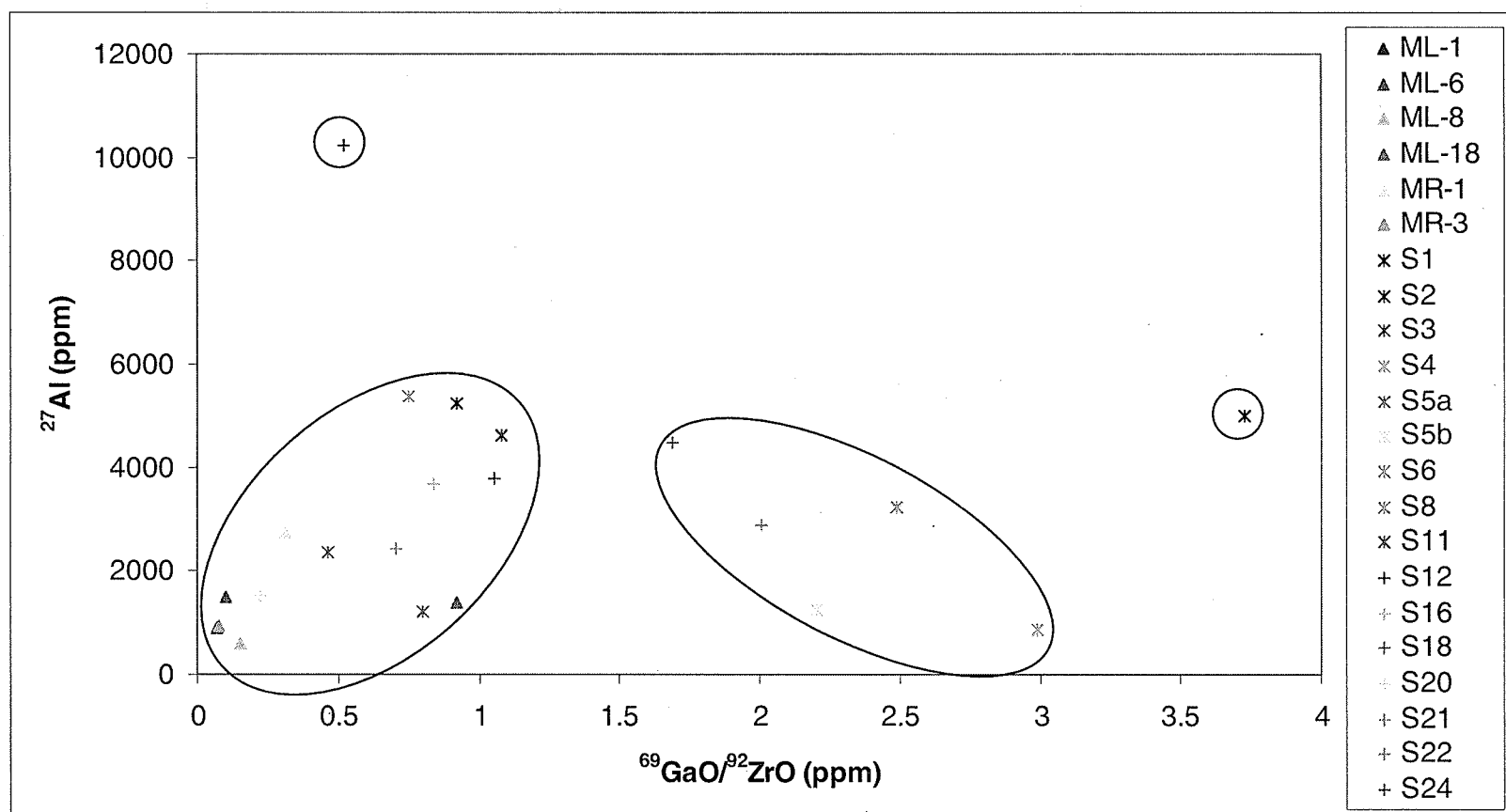


Figure 6.7 An inferential plot of the raw materials being selected during the Pre-Dorset period at LeDx-42

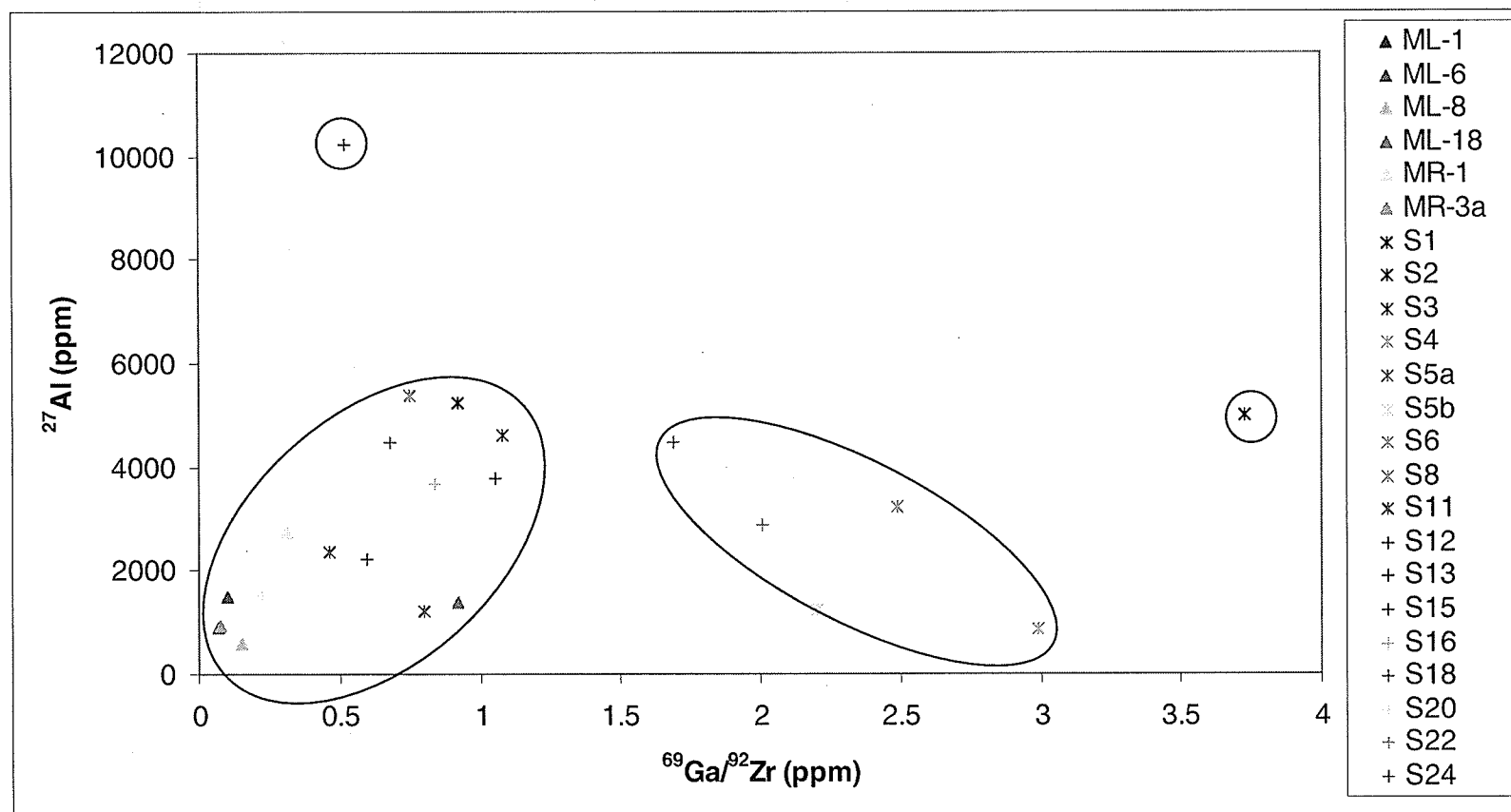


Figure 6.8 An inferential plot of the raw materials being selected during the Transitional period at LeDx-42

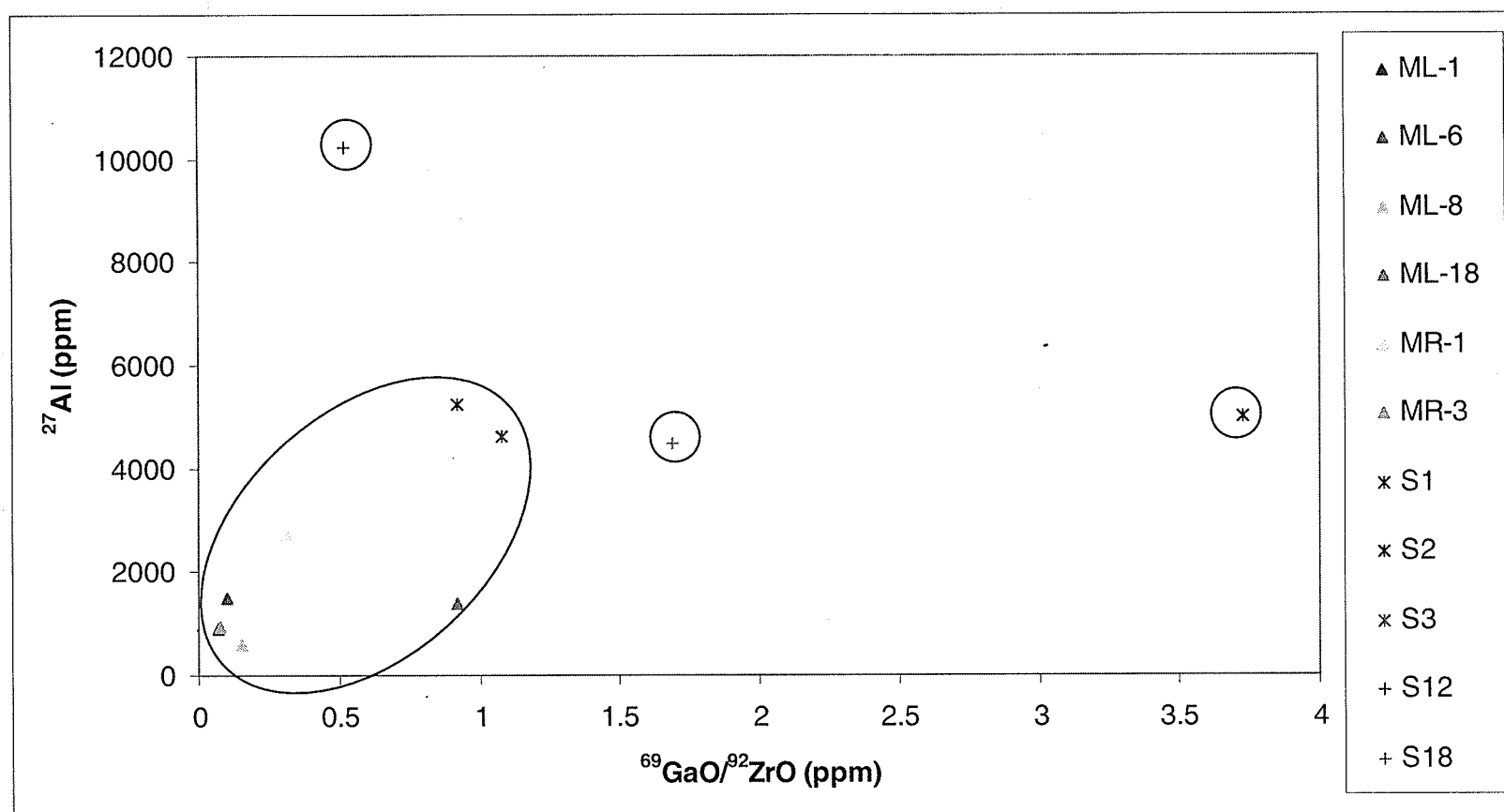


Figure 6.9 An inferential plot of the raw materials being selected during the Dorset period at LeDx-42

Conclusions

From these analyses it is apparent that visual analysis is entirely incapable of reliably sourcing lithic raw materials from the interior of southern Baffin Island. The raw chert and debitage source groups established using visual analysis were vastly inflated. Furthermore, in almost every case where raw materials were grouped using visual analysis the results were falsified by the trace element data. That said, IAA was useful as a qualitative tool to bring some kind of order to an otherwise random aggregation of multi-coloured raw material samples (see Milne *et al* 2007 a/b). Using colour, quality, and texture as a lowest common denominator, I was able to create and organize preliminary categories that could be geochemically fingerprinted using SIMS, and then compared quantitatively. Petrographic analyses were somewhat more reliable than macroscopic visual characterization but the method is still nowhere near accurate enough to be used alone in a raw material sourcing study.

Trace element analyses were successful in distinguishing four unique source groups. The six visually established raw material sources all come together within a single cluster suggesting they were all derived from a single source. The 24 established debitage categories cluster within four groups. This implies that the Palaeo-Eskimo were selecting raw materials derived from four geologically unique sources. Both the raw material and debitage categories established by IAA were reduced by six times when compared with trace element data.

Locally available raw materials are represented in three of these source groups and non-local and/or exotic raw materials in the last. These non-local raw materials are present in each occupational period, but only in very small amounts, and they are all from

a single geological source. Conversely, local raw materials were persistently the most common raw materials selected by the Palaeo-Eskimo. Indeed the same four visually established colour categories represent more than 90% of the total lithic assemblage throughout the 2400-year occupation of LeDx-42. Furthermore, early stage reduction attributes present on local debitage from the Pre-Dorset and Transitional periods and the observed full spectrum of flake sizes on local debitage from all three occupational periods indicates that the Palaeo-Eskimo were intensively exploiting local materials for tool manufacture almost to the exclusion of other lithic materials through their occupation of the site. Overall, raw material selection strategies changed very little at LeDx-42 during the Palaeo-Eskimo continuum. Locally available raw materials were by far the most commonly selected, and the proportion and nature of this selection remained near constant over time.

Based on these conclusions, the LeDx-42 lithic assemblage conforms to Hypothesis 1 outlined in Chapter 4. Therefore, we can assume that a radical shift in technological organization and preference for exotic raw materials did not occur between the Pre-Dorset and Dorset periods. Furthermore, because selection strategies remained consistent throughout all three cultural periods, the presumed climatic changes which occurred during the Transitional period did not affect or alter the specific Palaeo-Eskimo inland adaptation. Indeed, they continued to consistently return to the interior over a 2400-year period to exploit local lithic and subsistence resources.

Chapter 7

Summary and Conclusions

This chapter summarizes the research objectives outlined at the beginning of this study, the methods used to meet them, and the results. The implications of this study and its finding to Arctic archaeology and raw material sourcing studies are then discussed. Finally, future research considerations are outlined.

Summary: Research Objectives and Methodology

The objective of this research was to (1) develop an innovative geochemical analytical technique to reliably identify lithic raw material source areas from the interior of southern Baffin Island, and (2) understand how the Palaeo-Eskimo populations living there exploited these lithic resources over a 2400-year period. To meet these objectives, I examined locally available lithic raw materials from the Mingo and Amadjuak Lake Districts of southern Baffin Island, and debitage from the nearby LeDx-42 site.

LeDx-42 contains securely dated occupations spanning the entire Palaeo-Eskimo continuum, thus providing the unprecedented opportunity to observe raw material selection strategies over a 2400-year period. The site itself boasts a massive lithic assemblage that I was able to draw upon for my research, and the surrounding lithic

resources provided a base comparative sample upon which I was able to evaluate my data.

I constructed a series of multiple working hypotheses and related test expectations for the LeDx-42 lithic assemblage that were theoretically grounded in a technological organizational approach. I relied on traditional observational methods, petrographic, and trace element analyses to test these hypotheses, and the outcome of testing supports Hypothesis 1 presented Chapter 4. Lithic raw material selection strategies remained unchanged throughout the entire Palaeo-Eskimo occupation of the site, and inhabitants were primarily exploiting locally available lithic raw materials for their tool using needs. The geochemical component of my analysis successfully isolated four discrete source groupings from the raw materials and debitage present at LeDx-42, and successfully reduced the number of visually established source categories by six times (i.e. from 24 presumed categories to four discrete categories).

Implications of this Study for Arctic Archaeology

The results of this study will have significant implications for Arctic archaeology, and will add new depth to discussions on Palaeo-Eskimo raw material selection and culture change. As noted in Chapter 3, some archaeologists believe that changing patterns of raw material selection and use among the Palaeo-Eskimo represented a culture change between the Pre-Dorset and Dorset (e.g. Gramly 1978; Maxwell 1985; McGhee 1996; Schledermann 1990, 1996; Sutherland 1996; Nagy 1997, 2000). Generally, Pre-Dorset selection patterns were interpreted as less particular than those of the Dorset who were highly specific in their raw material choices. However, the results of this study do

not follow this assumption. Instead, the raw material selection strategies established during the Pre-Dorset period remained essentially unchanged throughout the 2400-year period that the site was occupied. Indeed, throughout the continuum, four of the 24 colour categories established in IAA represent more than 90% of the total lithic sample examined in this study, and these are all locally available raw materials.

This pattern does not conform with Nagy's (1997, 2000) interpretation of Palaeo-Eskimo raw material selection in Ivujivik. She believes that a group's knowledge of the land will influence how they select raw materials. Put into the context of the study area, Nagy believes that the first Pre-Dorset colonizers would have been unfamiliar with the landscape and consequently would have selected their lithic raw materials opportunistically and haphazardly. However, after more than a millennium of continual and habitual reoccupation, Dorset toolmakers would have been exceedingly familiar with the area's resources and would have only selected the finest raw materials available. This obviously is not the case at LeDx-42. Additionally, Pre-Dorset selection strategies were not haphazard. They were, in fact, very specific and obviously benefitted those who relied upon them. Otherwise they would not have persisted for so long.

Finally, some archaeologists believe that the Dorset selectively chose specific raw materials as markers of their identity (Loring 2002: 164; Maxwell 1973: 300; McGhee 1996: 136-40), and further Odess (1998:426) has suggested that the presence of widely recognizable raw materials like Ramah and Southampton Island Banded chert on Dorset sites was used as a means to maintain social ties over long distances. However, none of these materials are present in the LeDx-42 lithic assemblages. Some exotic raw materials are present at LeDx-42, but trace element analysis indicates that they all derive from a

single geological source, and their presence in the larger debitage assemblage is almost negligible.

Raw material selection strategies at LeDx-42 do not fit within the prevailing interpretations of Palaeo-Eskimo raw material selection strategies. Instead, they are distinct in their own right and are specific to the interior of southern Baffin Island and the availability of raw materials there.

Implications of this Study for Raw Material Sourcing

This research is important because it represents the first comprehensive study to use secondary ion mass spectrometry (SIMS) to source chert. Two preliminary studies of Baffin Island cherts had been done previously (Milne *et al* 2007a/b), and these are being expanded upon here. A detailed discussion of SIMS has already been presented in Chapter 5, however, its value to archaeological sourcing studies warrants reiteration here. First, it is minimally destructive leaving a mark of only ~10nm. This is extremely valuable to archaeologists. It allows archaeologists to retrieve valuable quantitative data from an artifact while maintaining its qualitative features. Secondly, it allows archaeologists to do *in situ* analysis on artifacts. Most instruments used to source raw materials (e.g. INAA, ICP) rely on bulk analyses where samples are crushed up and an averaged value of the entire sample is provided. In *in situ* analyses, the researcher is able to choose where he or she samples a stone, and has the additional option to sample it more than once. This proved to be especially valuable for my samples which contained a great deal of internal and external variability (see Appendix D). Using *in situ* SIMS analysis I was able to map the full range of variability present in my sample in a way that

would have been impossible to do using any other instrument. For these reasons, SIMS is a valuable tool in lithic raw material sourcing studies.

The use of geochemical analytical techniques to source lithic raw materials is integral. It was noted in Chapter 5 that sourcing studies that rely solely on traditional observational methods suffer from interpretive bias because archaeologists are forced to make subjective assessments of the stones to create groupings they believe are representative of the original source (e.g. Ahler 1989a/b; Larson 1994:58; Luedtke 1978:745; Odell 2004:30-31). For example, using visual analysis I characterized six debitage categories from the LeDx-42 site as exotic based on their fine grained and vitreous textures, relative absences of internal flaws and cortex, and small size. However, when these were compared to the trace element data, every “exotic” flake I characterized was attributed a “local” source group. By extension, it is entirely possible that other researchers who rely on visual analyses are making the same mistakes. Returning to Nagy (1997: 171, 2000: 146), she believes that the Dorset period is characterized by an increased presence of exotic raw materials. However, it is entirely possible that, like me, based on her visual analyses, she is over inflating actual patterns of diversity. Therefore, in order to ensure the reliability of results, a geochemical analytical technique should be used to source raw materials, especially when working with highly variable cherts.

Future Research Considerations

I plan to collect and test more raw samples of chert from the Mingo and Amadjuak Lake Districts. Debitage categories from two of the four source groups

established in this study from trace element concentrations appear to be local, but because no raw chert samples clustered with them they cannot definitively be classified as such. Therefore, I hope to collect additional samples from the study area and associate them with these other potentially “local” debitage categories.

An important objective of this research was to establish the number of locally available raw material sources present in the Mingo and Amadjuak Lake Districts of southern Baffin Island. These data now provide me with an important foundation upon which I can develop this research to create a more extensive inventory of the lithic raw material sources available in the Arctic. Additionally, I will expand this study for my upcoming PhD research. I plan to include a larger data set in my analysis and incorporate other inland sites in my study. This will allow me to perform a multi-scalar analysis of the southern Baffin Island inland ecosystem to assess how people were organizing their lithic technology over time at both the micro- and macro-scale.

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Appendix A

Debitage Identification and Attributes.

IDENTIFICATION

Identification and attributes are taken from Milne (2003).

A. Artifact Number: This entry specifies the number assigned to each artifact studies.

Each artifact is assigned a number and listed arbitrarily.

B. Temporal Period: This entry specifies the temporal period each artifact is associated with. Numbers are assigned arbitrarily to each site to distinguish them as follows:

- 1) Pre-Dorset
- 2) Transitional
- 3) Dorset

C. Unit Classification: This entry specifies the unit in which the artifact was recovered. Each unit is assigned an arbitrary number as follows:

- 1) F11
- 2) U3
- 3) Test 2
- 4) Test 4
- 5) Test 9
- 6) Test 11

RAW MATERIAL ATTRIBUTES

D. Raw Material Colour: This entry refers to the colour of the lithic raw material upon which the artifact is made. Colours comply with the charts published in the 1992 revised edition of the Munsell Soil Color Chart.

- 1) Light gray (hue 10YR, 7/1)

- 2) Gray (hue 5Y, 5/1), with light gray (2.5Y, 7/2)
- 3) Light gray (hue 2.5Y, 7/2), with light brownish gray (hue 10YR, 6/2)
- 4) White (gley, 8/), tinged dark reddish gray (hue 2.5YR, 5/1)
- 5) White (gley, 8/)
- 6) Light olive brown (hue 2.5Y, 5/3)
- 7) Swirled – reddish gray (hue 10R, 5/1), light brownish gray (hue 2.5Y, 6/2)
- 8) Banded – gray (hue 5Y, 5/1), light gray (hue 2.5Y, 7/2), gray (hue 10YR, 6/1)
- 9) Dark gray (hue 2.5Y, 4/1), grayish brown (hue 2.5Y, 5/2) (was 26)
- 10) Yellowish brown (hue 10YR, 5/4)
- 11) Banded – dark gray (hue 5Y, 4/1), white (hue 5Y, 8/1)
- 12) Gray (hue 10YR, 6/1), with gray (hue 5Y, 5/1)
- 13) Dark gray (hue 5YR, 4/1) (was 28)
- 14) White (hue 5Y, 8/1), gray (hue 5Y, 5/1)
- 15) Light gray (gley N6)
- 16) Grayish brown (hue 2.5Y, 5/2)
- 17) Banded – black (hue 5Y, 2.5/1), gray (hue 2.5Y, 5/1) (was 27)
- 18) Light yellowish brown (hue 2.5Y, 6/3)
- 19) White (gley, N8), gray (hue 5Y, 5/1), light yellowish brown (hue 2.5Y, 6/3) (was 25)
- 20) White (gley, N8), light gray (hue 7.5YR, 7/1)
- 21) Light gray (hue 2.5Y, 7/1), with white (gley, N8)
- 22) Pale Yellow 2.5Y, 7/4)
- 23) Pinkish Gray (hue 7.5Y, 7/2)
- 24) Black (hue 5Y, 2.5/1)

E. **Lithic Raw Material Texture:** This entry refers to both the macroscopic and microscopic texture observed in each raw material type. The following textures are considered in this study:

- 1) Vitreous: Individual grains making up the rock are so homogeneous, small and tightly packed together that they are not visible through a 10X magnifying lens
- 2) Fine Grained: Individual grains are relatively homogeneous, and discernable through a 10X magnifying lens, but not to the “naked eye”.
- 3) Coarse grained: Individual Grains are heterogeneous, and discernable without the aid of a 10X magnifying lens
- 4) Very Coarse Grained: Individual grains are very heterogeneous, and easily discernable

F. **Lithic Raw Material Quality:** Quality refers to the presence (1) or absence (0) of inclusions, vugs, voids, and/or fossils within the raw material from which the artifact is

made. This entry is a measure of homogeneity versus heterogeneity of the raw material which is important in understanding flake detachment. Materials with internal flaws may compromise successful detachment of a flake and/or the completion of an artifact.

G. Cortex: This entry indicates the amount of cortex present on the dorsal surface and/or platform of each artifact. Cortex is produced by the chemical (e.g. exposure to moisture or heat) or mechanical (e.g. abrasion) weathering of the stone's surface

(Andrefsky 1998: 101). In this study a ranked scale will be used to measure the amount of dorsal and/or platform cortex: (Andrefsky 1998: 103-104).

- 0) Absent
- 1) 1-49%
- 2) 50-99%
- 3) 100%
- 4) Platform only

Appendix B

Debitage Identification and Attributes of Artifacts Selected for Destructive Analysis.

IDENTIFICATION

Identification and attributes are taken from Milne (2003).

A. Artifact Number: This entry specifies the number assigned to each artifact studies. Each artifact is assigned a number and listed arbitrarily.

B. Temporal Period: This entry specifies the temporal period each artifact is associated with. Numbers are assigned arbitrarily to each site to distinguish them as follows:

- 1) Pre-Dorset
- 2) Transitional
- 3) Dorset

C. Unit Classification: This entry specifies the unit in which the artifact was recovered. Each unit is assigned an arbitrary number as follows:

- 1) F11
- 2) U3
- 3) Test 2
- 4) Test 4
- 5) Test 9
- 6) Test 11

RAW MATERIAL ATTRIBUTES

Identification and attributes are taken from Milne (2003).

D. Raw Material Colour: This entry refers to the colour of the lithic raw material upon which the artifact is made. Colours comply with the charts published in the 1992 revised edition of the Munsell Soil Color Chart.

- 1) Light gray (hue 10YR, 7/1)
- 2) Gray (hue 5Y, 5/1), with light gray (2.5Y, 7/2)
- 3) Light gray (hue 2.5Y, 7/2), with light brownish gray (hue 10YR, 6/2)
- 4) White (gley, 8/), tinged dark reddish gray (hue 2.5YR, 5/1)
- 5) White (gley, 8/)
- 6) Light olive brown (hue 2.5Y, 5/3)
- 7) Swirled – reddish gray (hue 10R, 5/1), light brownish gray (hue 2.5Y, 6/2)
- 8) Banded – gray (hue 5Y, 5/1), light gray (hue 2.5Y, 7/2), gray)hue 10YR, 6/1)
- 9) Dark gray (hue 2.5Y, 4/1), grayish brown (hue 2.5Y, 5/2) (was 26)
- 10) Yellowish brown (hue 10YR, 5/4)
- 11) Banded – dark gray (hue 5Y, 4/1), white (hue 5Y, 8/1)
- 12) Gray (hue 10YR, 6/1), with gray (hue 5Y, 5/1)
- 13) Dark gray (hue 5YR, 4/1) (was 28)
- 14) White (hue 5Y, 8/1), gray (hue 5Y, 5/1)
- 15) Light gray (gley N6)
- 16) Grayish brown (hue 2.5Y, 5/2)
- 17) Banded – black (hue 5Y, 2.5/1), gray (hue 2.5Y, 5/1) (was 27)
- 18) Light yellowish brown (hue 2.5Y, 6/3)
- 19) White (gley, N8), gray (hue 5Y, 5/1), light yellowish brown (hue 2.5Y, 6/3) (was 25)
- 20) White (gley, N8), light gray (hue 7.5YR, 7/1)
- 21) Light gray hue 2.5Y, 7/1), with white (gley, N8)
- 22) Pale Yellow 2.5Y, 7/4)
- 23) Pinkish Gray (hue 7.5Y, 7/2)
- 24) Black (hue 5Y, 2.5/1)

E. Lithic Raw Material Texture: This entry refers to both the macroscopic and microscopic texture observed in each raw material type. The following textures are considered in this study:

- 1) Vitreous: Individual grains making up the rock are so homogeneous, small and tightly packed together that they are not visible through a 10X magnifying lens
- 2) Fine Grained: Individual grains are relatively homogeneous, and discernable through a 10X magnifying lens, but not to the “naked eye”.
- 3) Coarse grained: Individual Grains are heterogeneous, and discernable without the aid of a 10X magnifying lens
- 4) Very Coarse Grained: Individual grains are very heterogeneous, and easily discernable

F. Lithic Raw Material Quality: Quality refers to the presence (1) or absence (0) of inclusions, vugs, voids, and/or fossils within the raw material from which the artifact is

made. This entry is a measure of homogeneity versus heterogeneity of the raw material which is important in understanding flake detachment. Materials with internal flaws may compromise successful detachment of a flake and/or the completion of an artifact.

G. Cortex: This entry indicates the amount of cortex present on the dorsal surface and/or platform of each artifact. Cortex is produced by the chemical (e.g. exposure to moisture or heat) or mechanical (e.g. abrasion) weathering of the stone's surface (Andrefsky 1998: 101). In this study a ranked scale will be used to measure the amount of dorsal and/or platform cortex: (Andrefsky 1998: 103-104).

- 0) Absent
- 1) 1-49%
- 2) 50-99%
- 3) 100%
- 4) Platform only

H. Size Grade: This entry specifies the maximum dimension of an artifact in, millimetres, using wire mesh stacking screens.

- 1) 13-19 mm (1/2 inch)
- 2) 20-25 mm (3/4 inch)
- 3) 26-30 mm (1 inch)
- 4) >31 mm (1 1/4 inch)

I. Weight: Weight will be measured in grams, rounded to the nearest decigram, using a digital scale.

J. Platform: This attribute refers to the presence or absence of a striking platform on debitage, and whether or not the initiation face of the flake has been modified prior or during flake removal. Six states of platform preparation are recognized.

- 0) Indeterminate
- 1) Unmodified: The initiation face is unmodified and covered in cortex. This type of platform is generally associated with initial core reduction or nodule testing (Andrefsky 1998).

- 2) Single flake removal: The platform is composed of a single flake scar. This state is generally associated with earlier stages of reduction (Andrefsky 1998; Shott 1994).
- 3) Multiple flake removal: The platform is composed of two or more flake scars. This state reflects the extensive platform preparation necessary for the latest or finishing stages of reduction (Magne 1985; Odell 1989)
- 4) Multiple flake removal with crushing or heavy force: The striking displays evidence of crushing or heavy force which is often associated with bipolar or hard hammer percussion (Ahler 1989).
- 5) Single flake removal with cortex.
- 6) Multiple flake removal with cortex.

K. **Eraillure Scar:** The eraillure is a small scar located on bulb of percussion which is the result of excessive force when detaching flakes (Andrefsky 1998; Cotterell and Kaminga 1990; Kooyman 2000; Odell 2004). The attribute is recorded as either present (1) or absent (0).

L. **Dorsal Scar Count:** This entry refers to the number of scars present on the dorsal surface of debitage. The dorsal scar count is measured and recorded as a numerical value, with a value of zero being attributed to flakes with no, or an indeterminate number of flake scars.

M. **Bulb of Percussion:** The bulb of percussion is refers to the rounded bulge located just below the striking platform of a flake on its ventral side (Andrefsky 1998; Cotterell and Kaminga 1990; Odell 2004). The attribute is measured as either present (1) or absent

N. **Compression Rings:** Compression rings are the ripple which radiate from the striking platform on the central surface of a flake (Crabtree 1972). Rings of compression are used as an indicator of the location of applied force in the absence of a striking platform (Odell 2004). The attribute is recorded as present (1) or absent (0).

O. Completeness Index: This entry assigns states of completeness to debitage. Five states of completeness are recognized.

- 0) Indeterminate
- 1) Shatter: A flake without a recognizable interior surface or point of applied force.
- 2) Proximal: A flake with a recognizable interior surface and point of applied force that lacks complete lateral and/or distal margins.
- 3) Distal: A flake with recognizable interior surface and distal margins that lacks the point of applied force on the proximal end.
- 4) Split: A flake with a recognizable interior surface, complete distal and lateral margins and a discernable point of applied force that is split longitudinally.
- 5) Complete: A flake with a recognizable interior surface, complete distal and lateral margins and a discernable point of applied force.

P. Distal Termination Type: This attribute refers to the type of flake termination observed on the distal end of debitage (Andrefsky 1998). A total of six termination types are recognized.

- 0) Indeterminate
- 1) Feather: A smooth terminations that gradually shears the flake away from the core.
- 2) Snap: A termination where the flake snaps upon termination to for a 90° angle with the ventral surface.
- 3) Step: A termination where there is an abrupt change in the fracture path of a flake. As a result, part of the detached flake remains on the core and the distal end of the flake appears to be stepped.
- 4) Hinge: A termination where the distal end of the flake is rounded or slopped.
- 5) Outrepasse: A termination where the fracture path curves markedly towards the distal end of the core and continues directly into the core, removing the base of the core and giving the flake a J shape in longitudinal cross section.

Q. Proximal Termination Type: This attribute refers to the type of flake termination observed on the proximal end of debitage (Andrefsky 1998). A total of five termination types are recognized.

- 0) Indeterminate
- 1) Snap: A termination where the flake snaps upon termination to for a 90° angle with the ventral surface.

- 2) Step: A termination where there is an abrupt change in the fracture path of a flake. As a result, part of the detached flake remains on the core and the distal end of the flake appears to be stepped.
- 3) Hinge: A termination where the distal end of the flake is rounded or slopped.

R. Right and Left Lateral Termination Types: This entry refers to the type of termination observed on the left and right lateral margins of a flake. The left and right margins of each flake are defined with the dorsal surface facing up and the proximal surface facing away from the observer.

- 0) Indeterminate
- 1) Feather: A smooth terminations that gradually shears the flake away from the core.
- 2) Snap: A termination where the flake snaps upon termination to for a 90° angle with the ventral surface.
- 3) Step: A termination where there is an abrupt change in the fracture path of a flake. As a result, part of the detached flake remains on the core and the distal end of the flake appears to be stepped.
- 4) Hinge: A termination where the distal end of the flake is rounded or slopped.
- 5) Outrepasse: A termination where the fracture path curves markedly towards the distal end of the core and continues directly into the core, removing the base of the core and giving the flake a J shape in longitudinal cross section.

Appendix C

Calculations for SIMS Analysis

First, the Relative Sensitivity Factor (F_i) of each trace element used in the study was determined by dividing the true value of each trace element (M_{true}) by the concentration of the same trace element present in the NIST 614 Glass Standard (M_{std}).

$$F_i = M_{\text{true}}/M_{\text{std}}$$

The true values of ^{69}Ga and ^{92}Zr were taken from Kurosawa *et al* (2002: 78), and the true values of Si and ^{27}Al were taken from Hollocher and Ruiz (1995: 31). The M_{true} of each trace element was determined by dividing the value of the element by the value of Si (e.g. Al/Si). SIMS was used on NIST 614 SRM 614 reference glass materials to determine the M_{std} concentrations of ^{92}Zr , ^{69}Ga , and ^{27}Al .

Following this, the corrected value of each trace element (M_{corr}) was determined by multiplying F_i , the measured value of the trace element present in the chert sample (M_{sample}), and the average quantity of silica present in chert.

$$M_{\text{corr}} = F_i \times M_{\text{sample}} \times \text{SiO}_2$$

The value of SiO_2 used in the study was taken from Luedtke (1992: 39) who notes that the proportion of silica present in most cherts ranges between 90% and 99%. Therefore, the value of SiO_2 used was 94.5%.

Appendix D

Raw Material and Debitage Thin Sections

- Figure D.1 ML-1 thin section sample, 4X magnification
- Figure D.2 ML-6 thin section sample, 4X magnification
- Figure D.3 ML-8 thin section sample, 4X magnification
- Figure D.4 ML-18 thin section sample, 4X magnification
- Figure D.5 MR-1 thin section sample, 10X magnification
- Figure D.6a MR-3 thin section sample, 4X magnification
- Figure D.6 b MR-3 thin section sample, 4X magnification
- Figure D.7 S1 thin section sample, 4X magnification
- Figure D.8 S3 thin section sample, 4X magnification
- Figure D.9 S4 thin section sample, 4X magnification
- Figure D.10 S5a thin section sample, 4X magnification
- Figure D.11 S5b thin section sample, 4X magnification
- Figure D.12 S6 thin section sample, 4X magnification
- Figure D.13 S8 thin section sample, 4X magnification
- Figure D.14 S11 thin section sample, 4X magnification
- Figure D.15 S12 thin section sample, 4X magnification
- Figure D.16 S13 thin section sample, 4X magnification
- Figure D.17 S15 thin section sample, 10X magnification
- Figure D.18 S16 thin section sample, 4X magnification
- Figure D.19 S18 thin section sample, 4X magnification

Figure D.20 S20 thin section sample, 4X magnification

Figure D.21 S21 thin section sample, 4X magnification

Figure D.22 S22 thin section sample, 4X magnification

Figure D.23 S24 thin section sample, 4X magnification

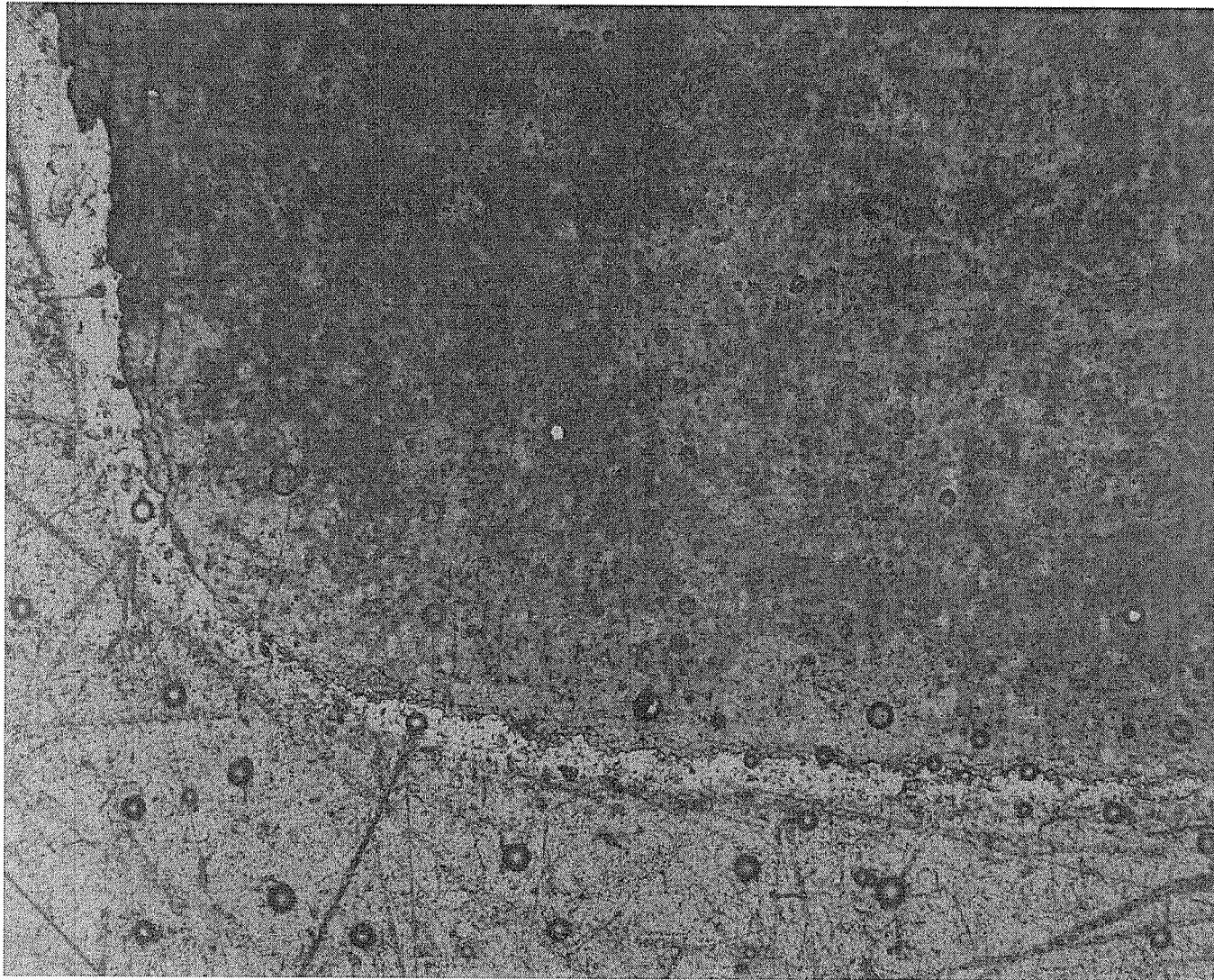


Figure D.1 ML-1 thin section sample, 4X magnification

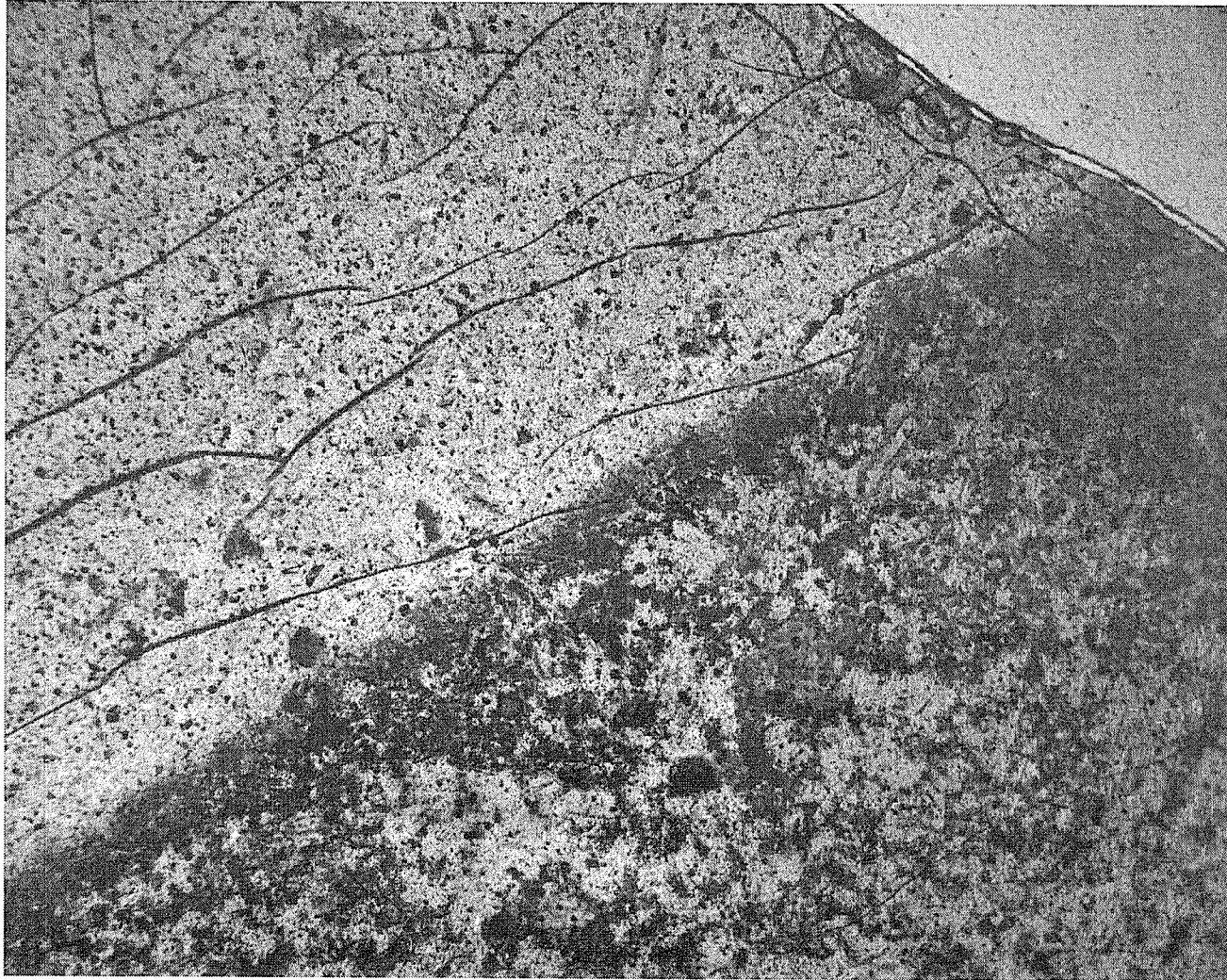


Figure D.2 ML-6 thin section sample, 4X magnification

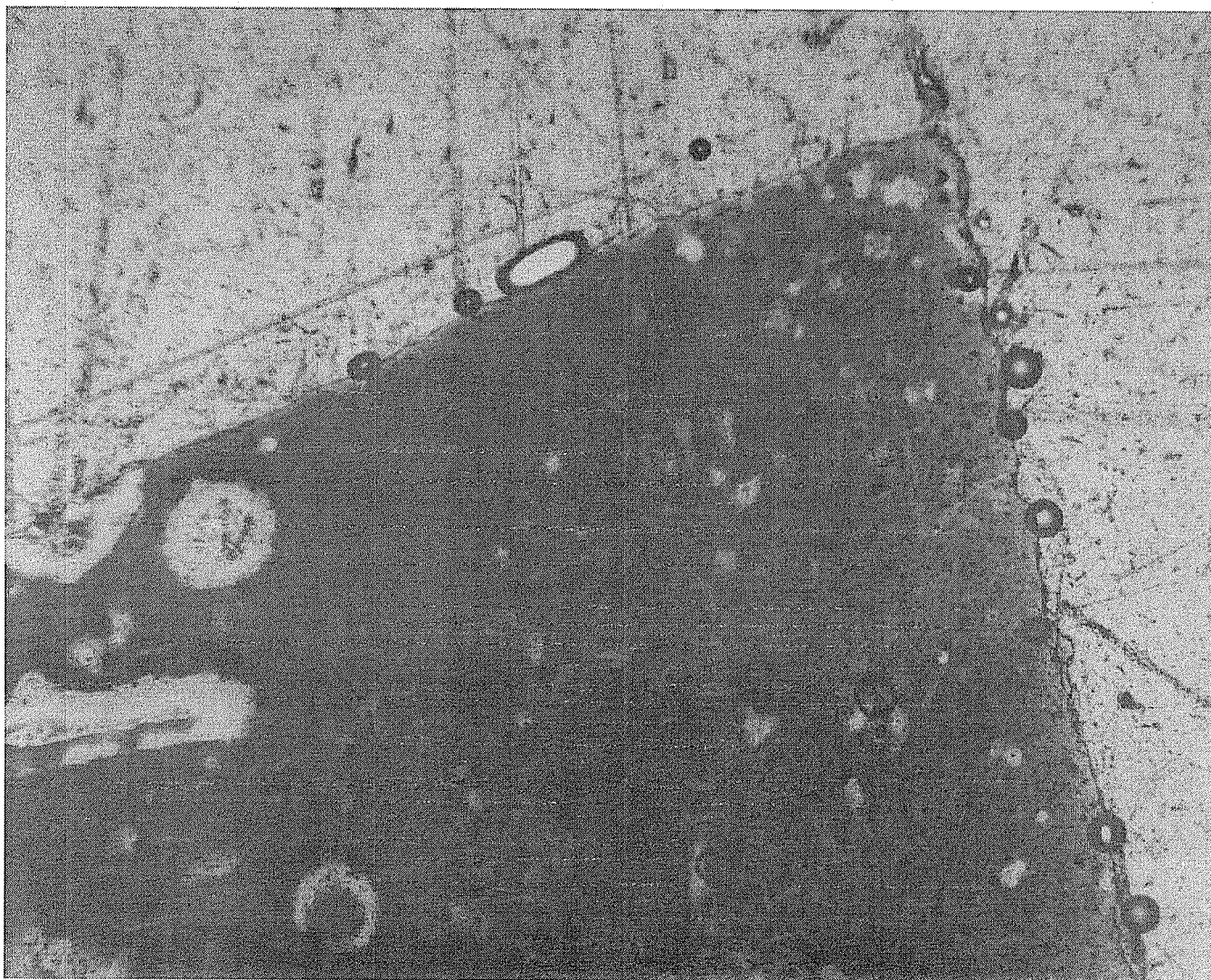


Figure D.3 ML-8 thin section sample, 4X magnification



Figure D.4 ML-18 thin section sample, 4X magnification

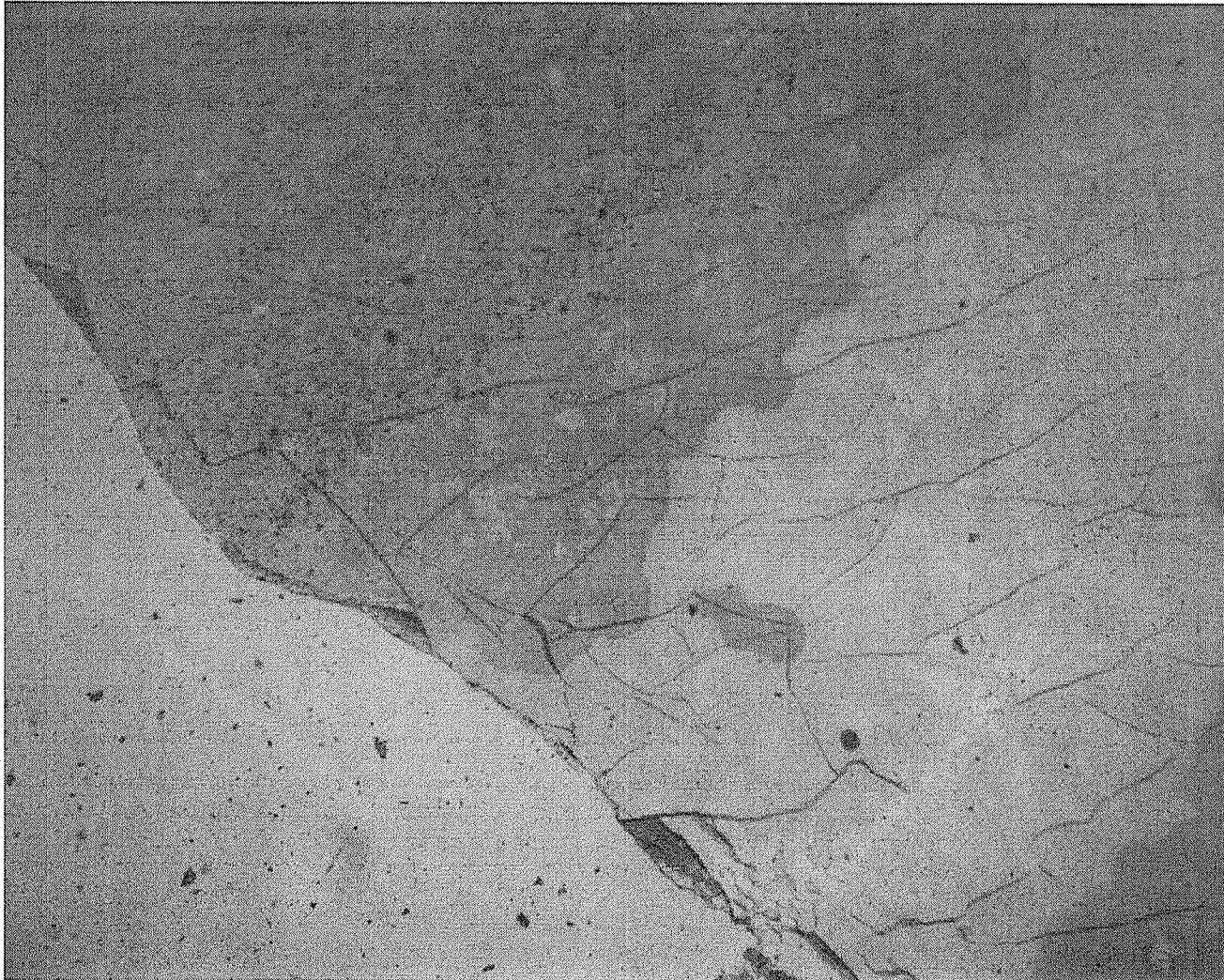


Figure D.5 MR-1 thin section sample, 10X magnification

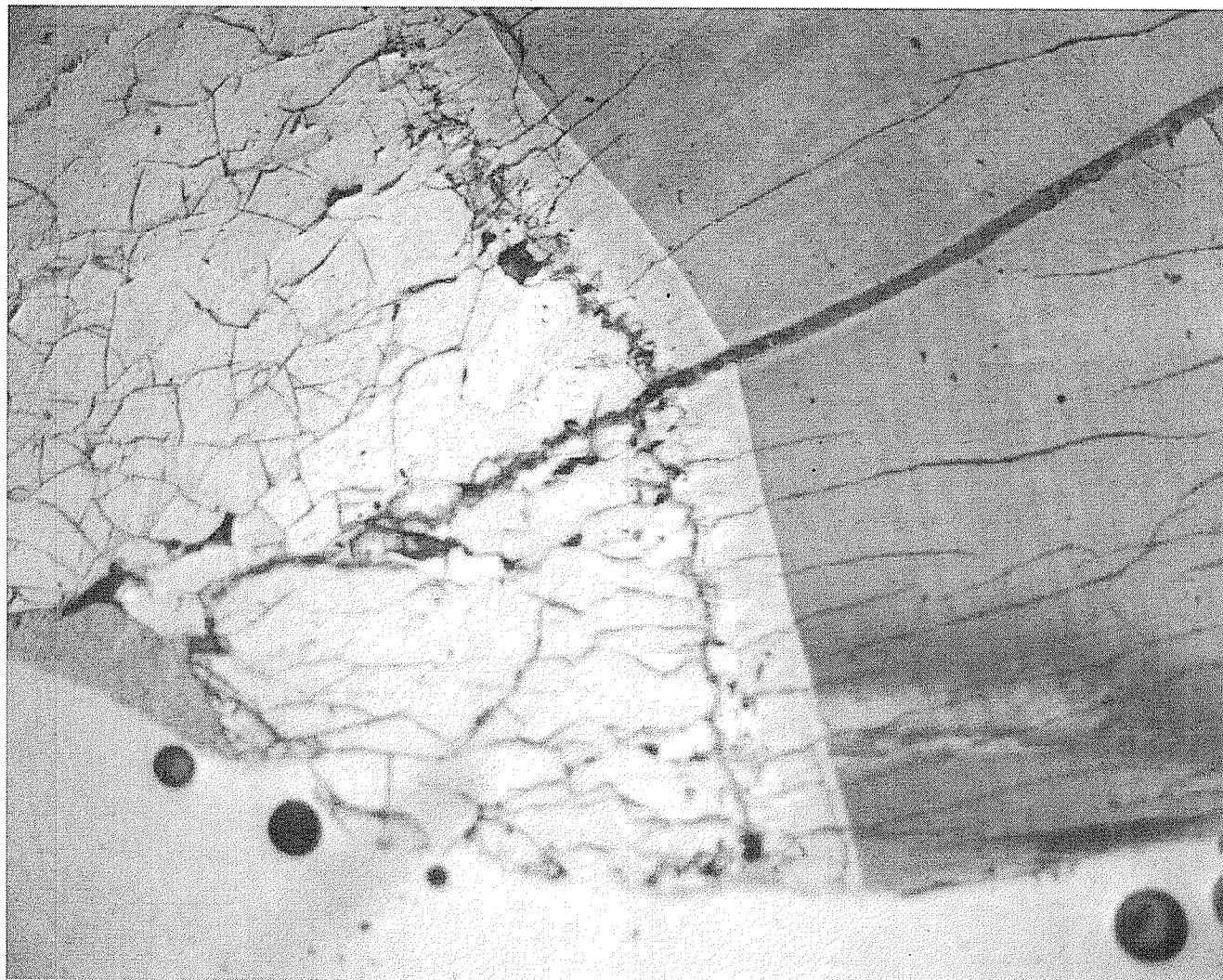


Figure D.6a MR-3 thin section sample, 4X magnification

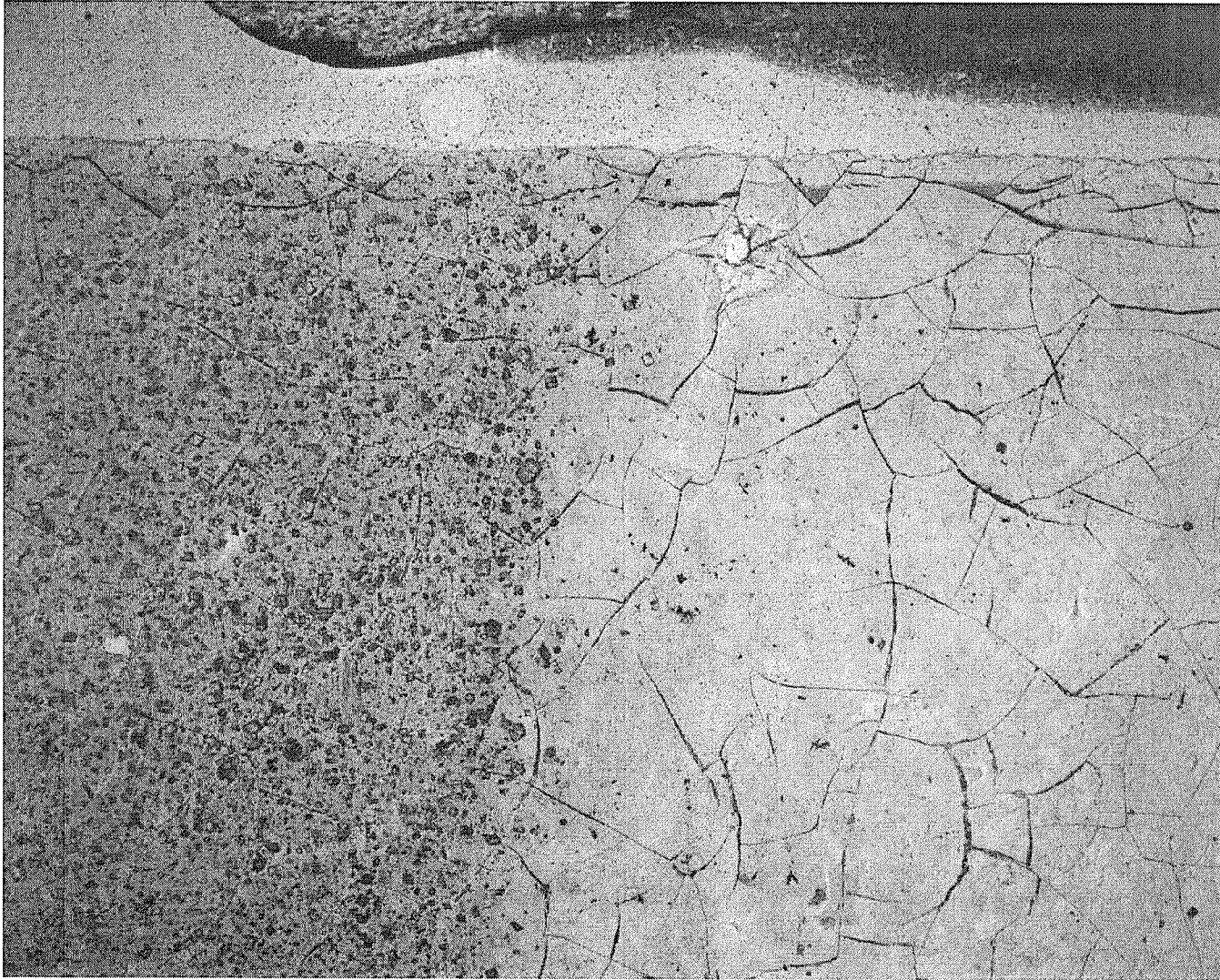


Figure D.6b MR-3 thin section sample, 4X magnification



Figure D.7 S1 thin section sample, 4X magnification

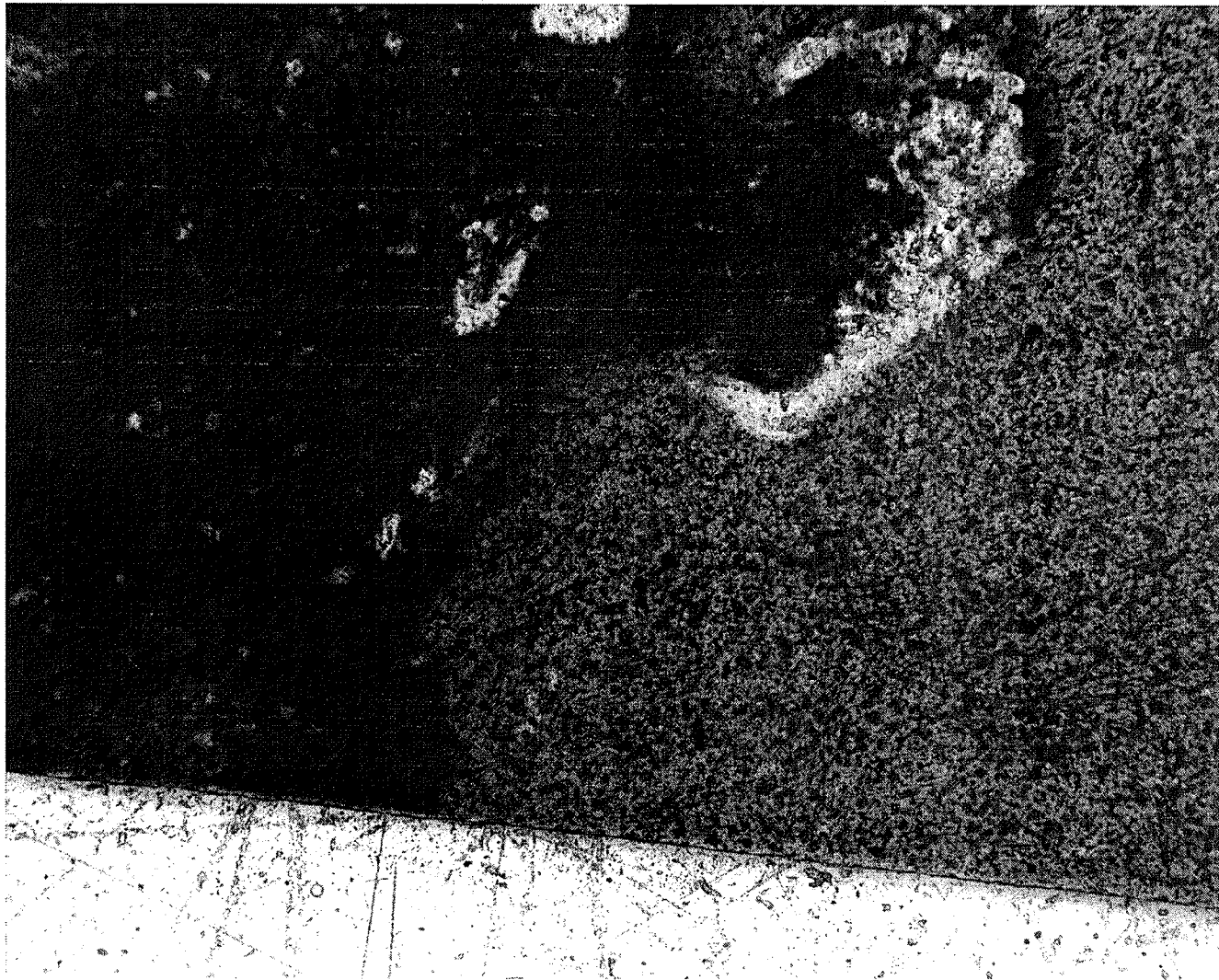


Figure D.8 S3 thin section sample, 4X magnification

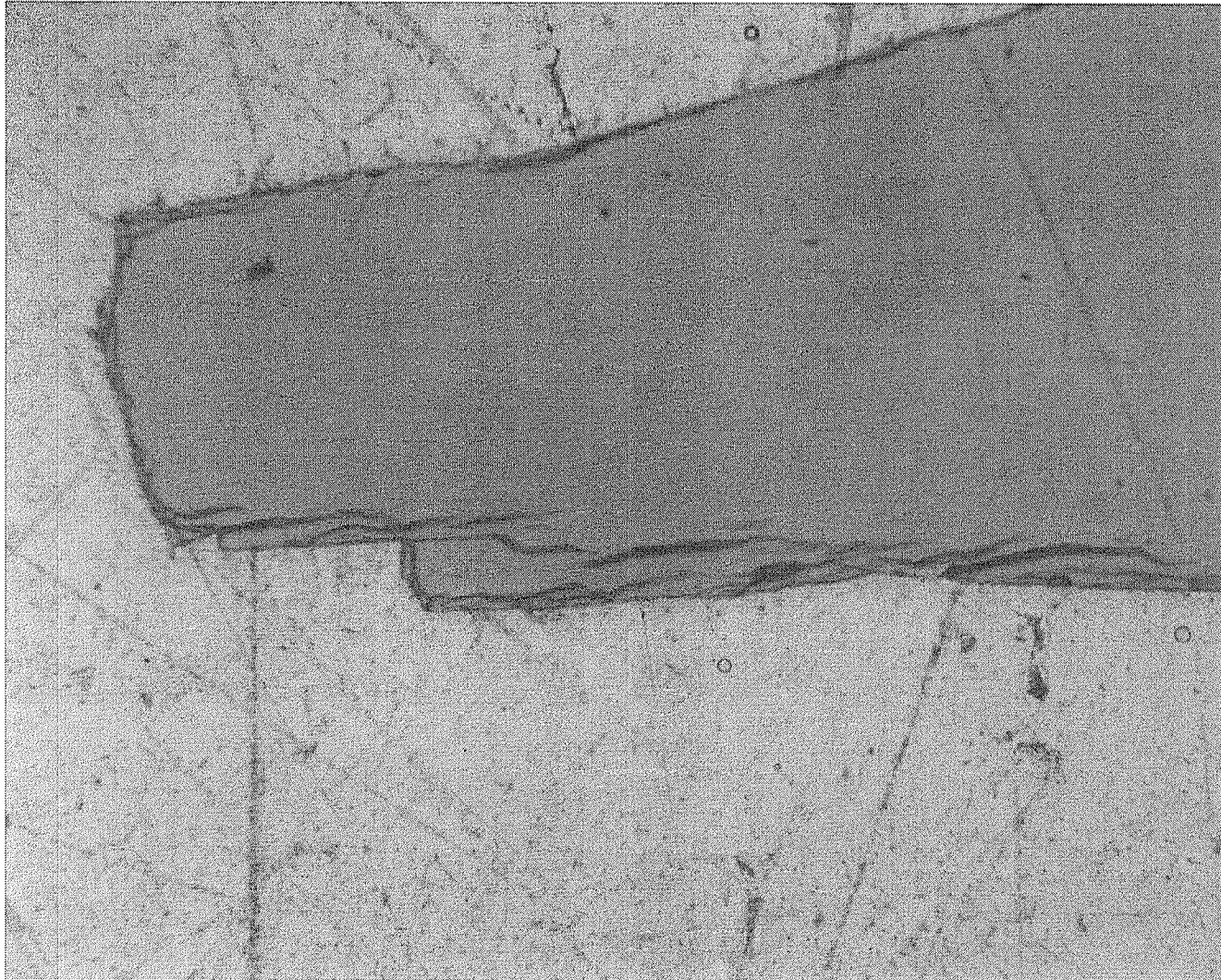


Figure D.9 S4 thin section sample, 4X magnification

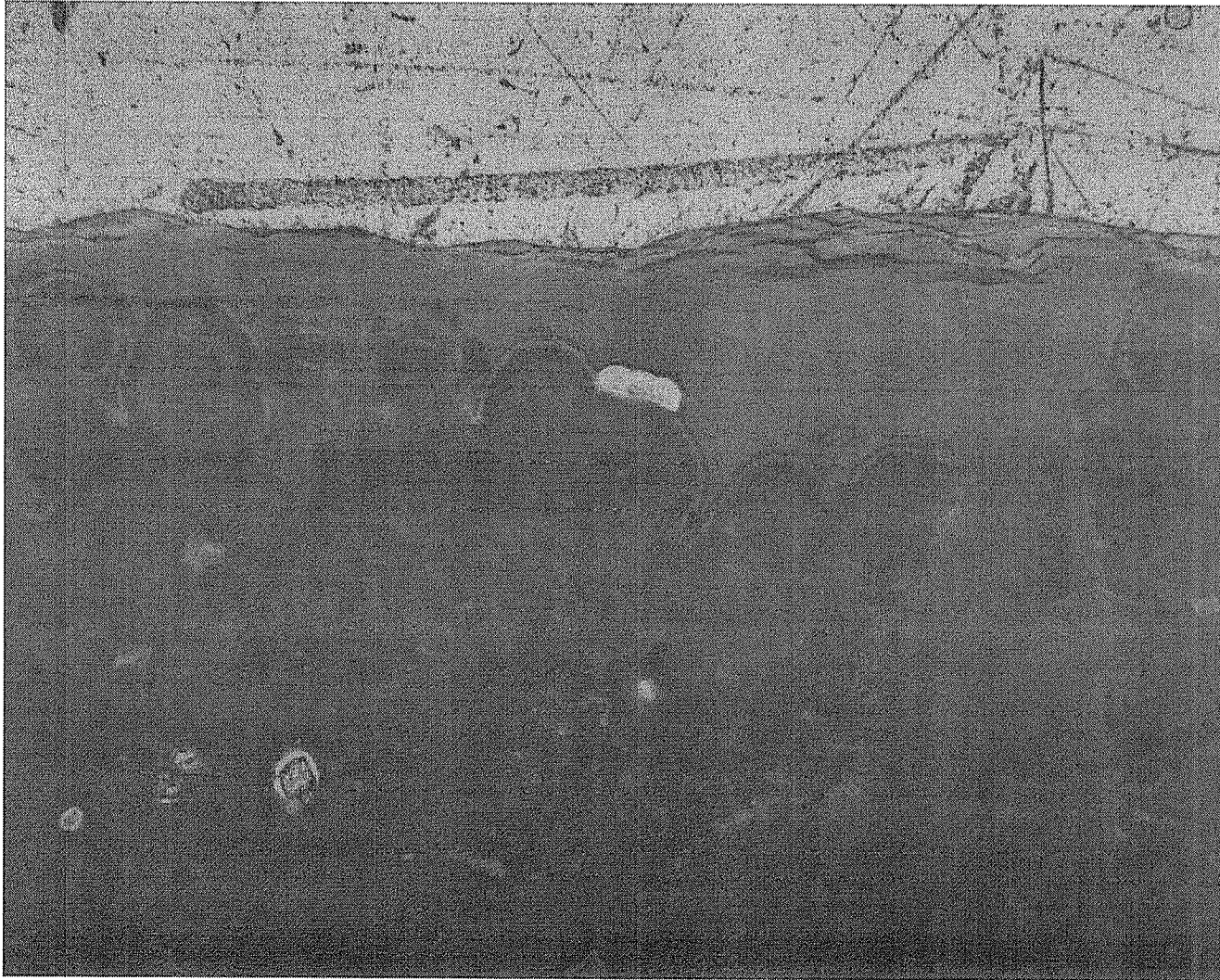


Figure D.10 S5a thin section sample, 4X magnification

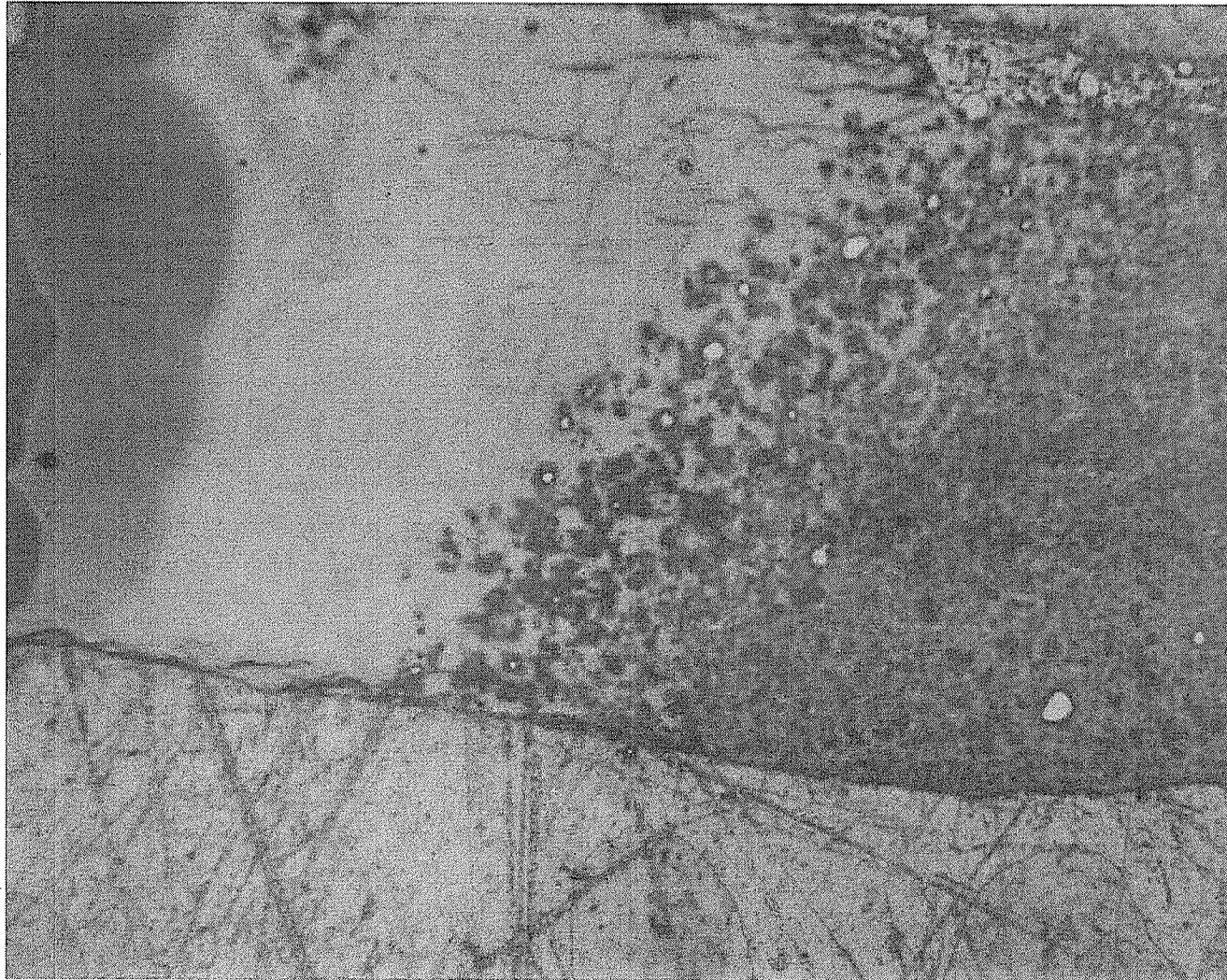


Figure D.11 S5b thin section sample, 4X magnification

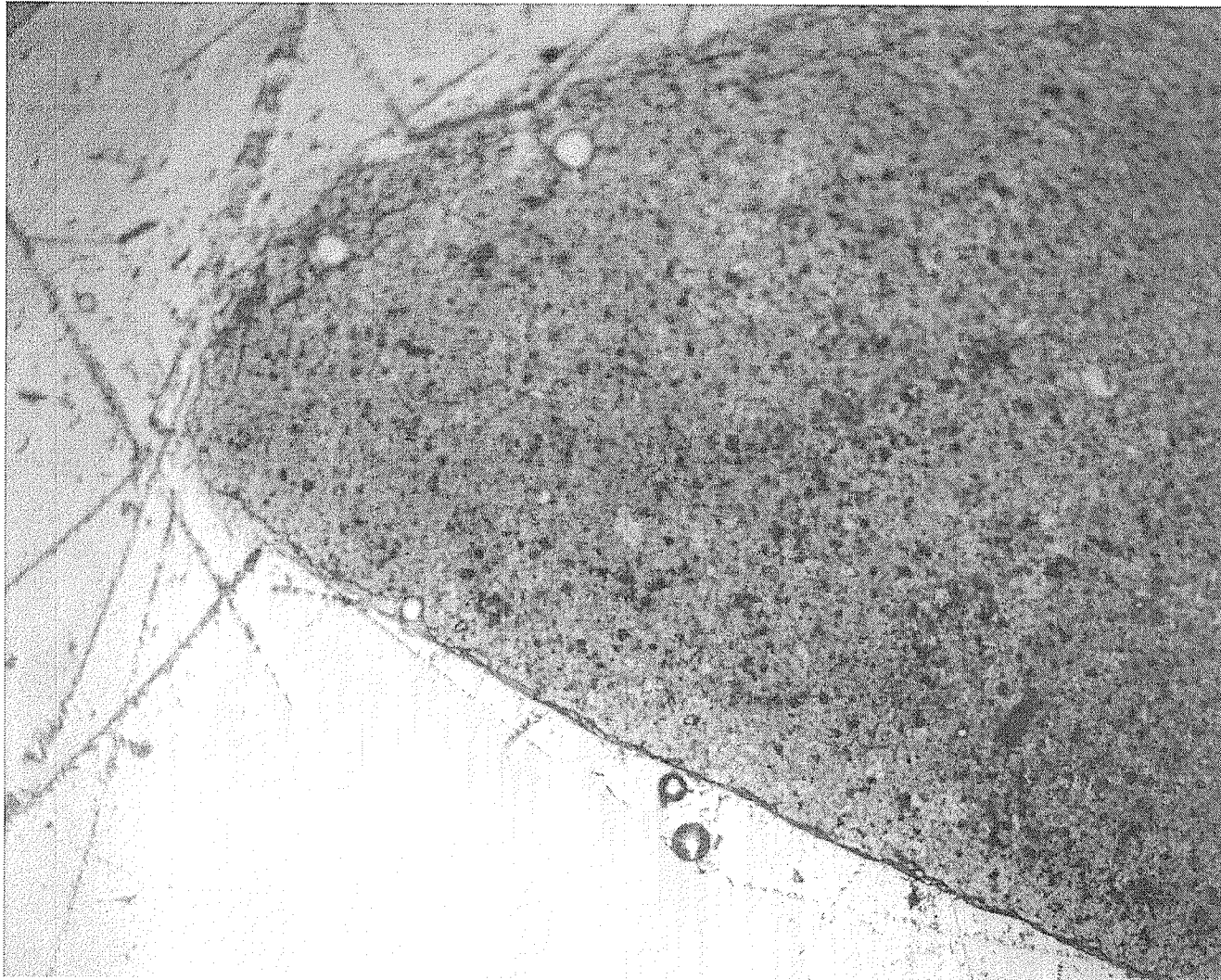


Figure D.12 S6 thin section sample, 4X magnification

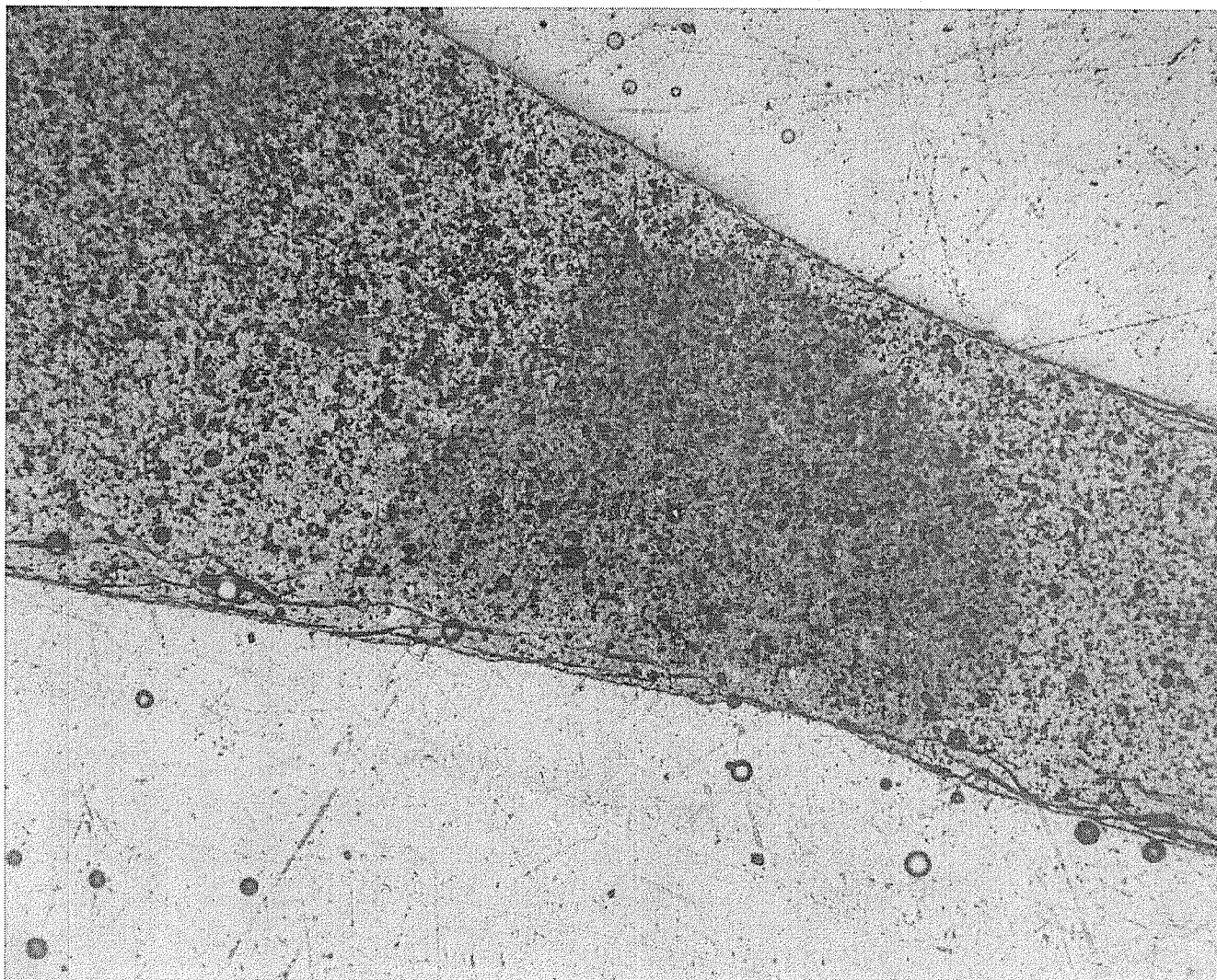


Figure D.13 S8 thin section sample, 4X magnification

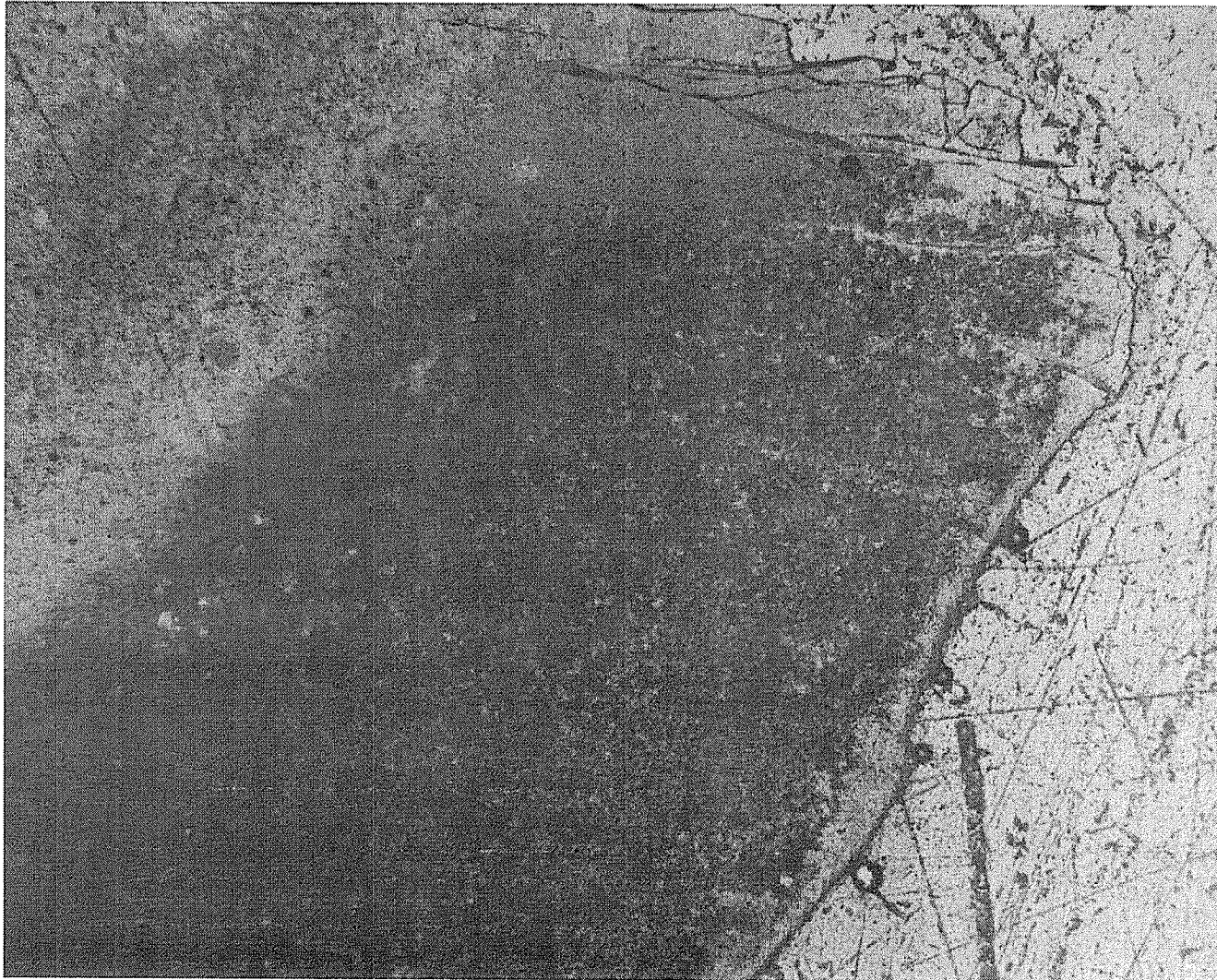


Figure D.14 S11 thin section sample, 4X magnification

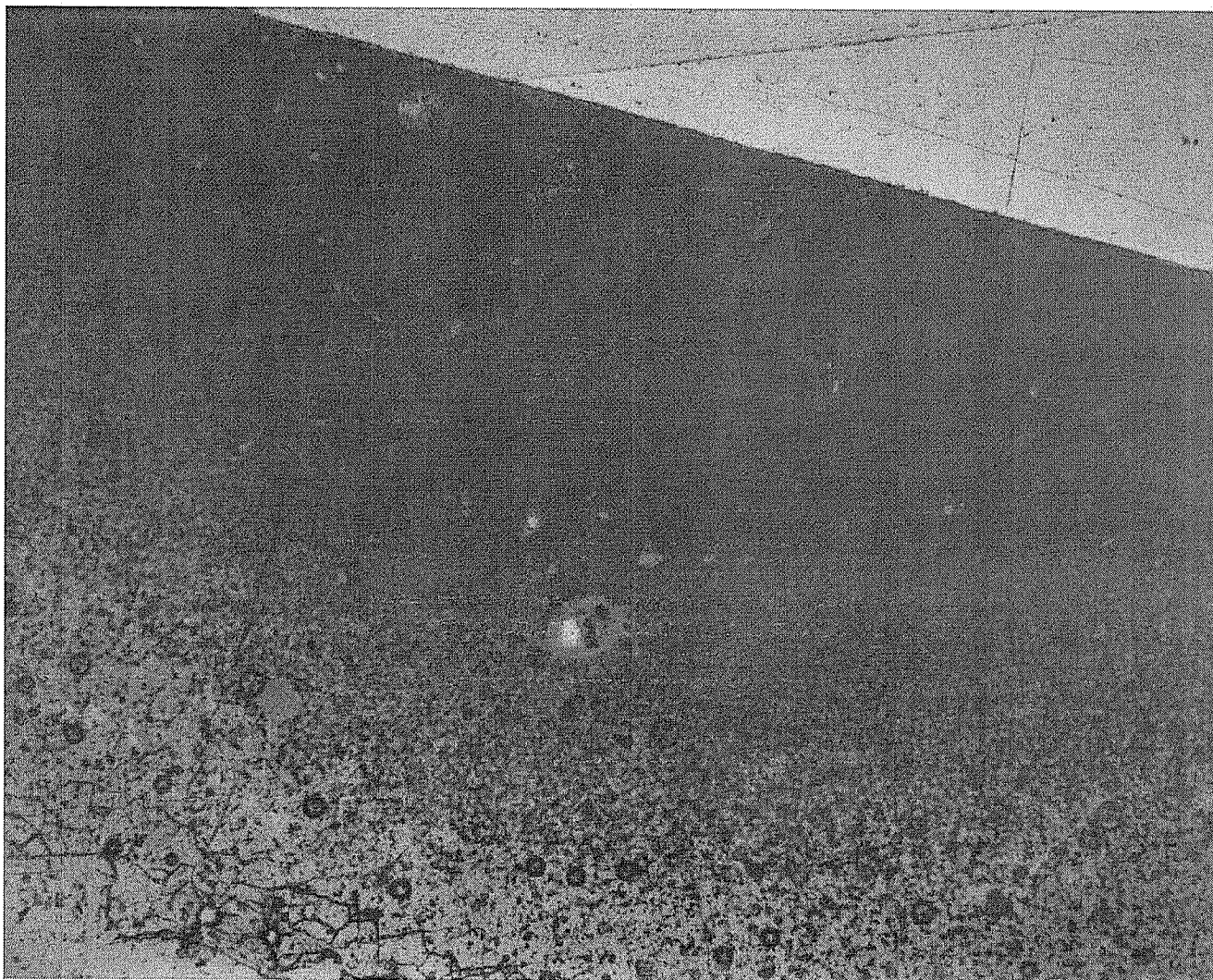


Figure D.15 S12 thin section sample, 4X magnification

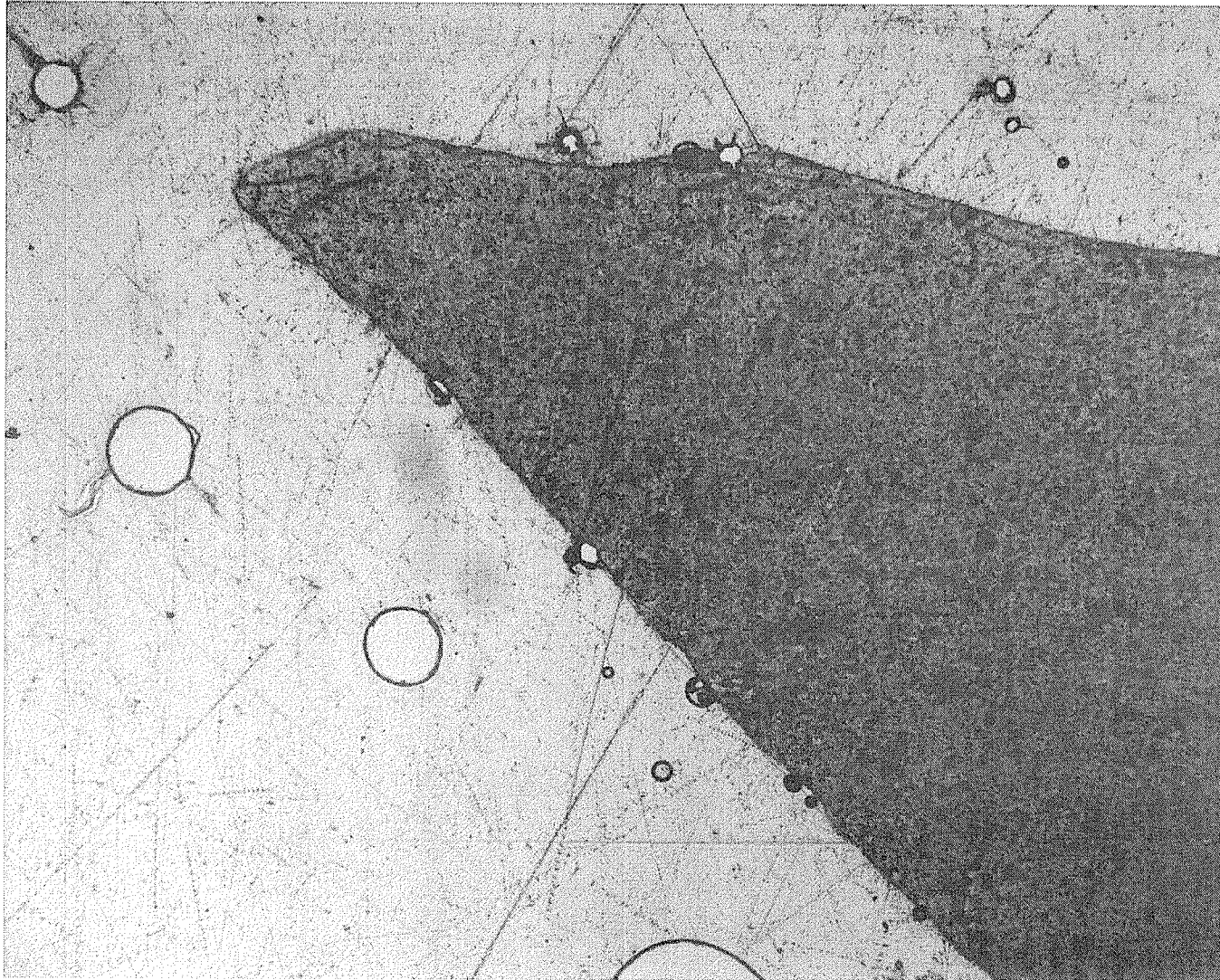


Figure D.16 S13 thin section sample, 4X magnification

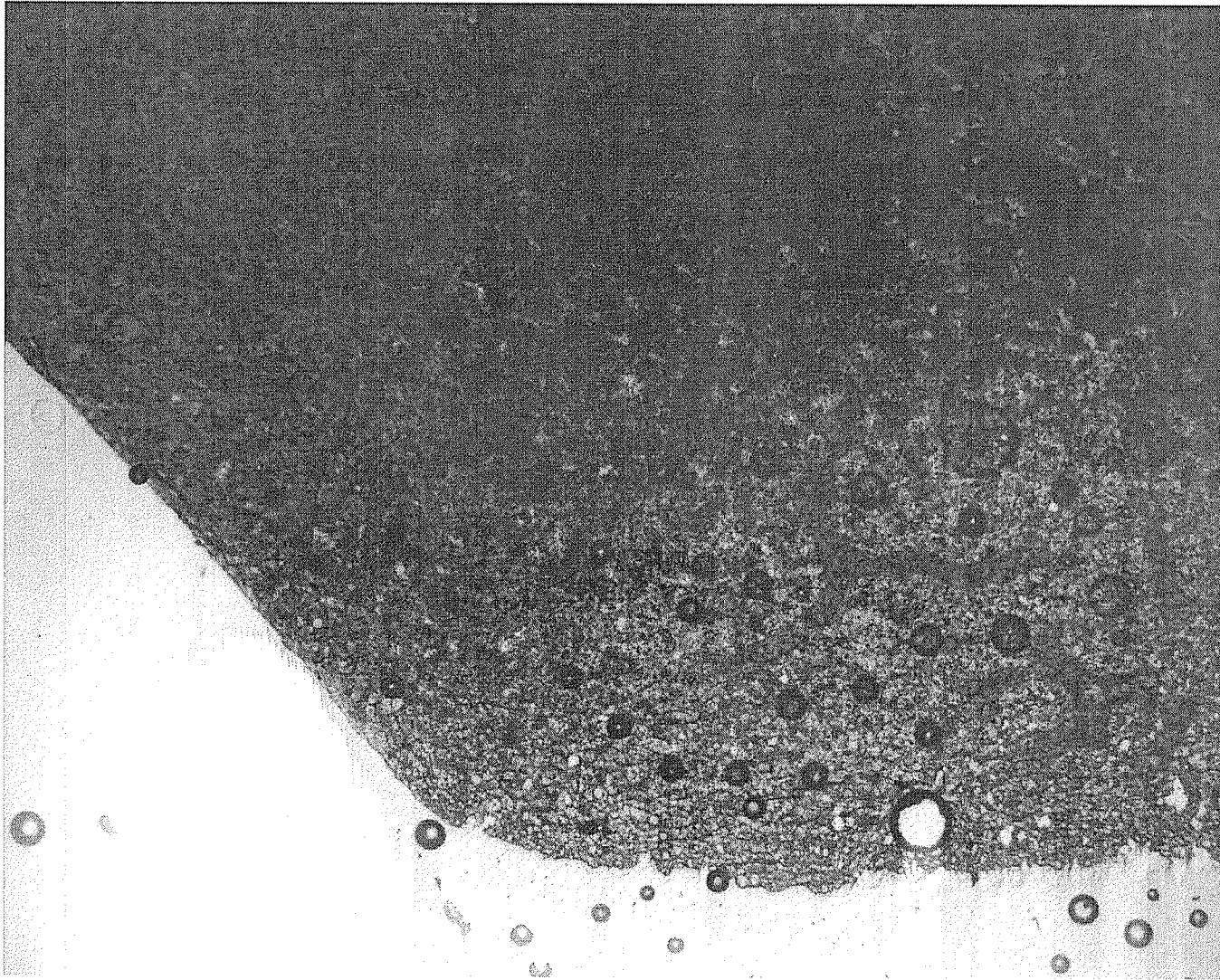


Figure D.17 S15 thin section sample, 4X magnification

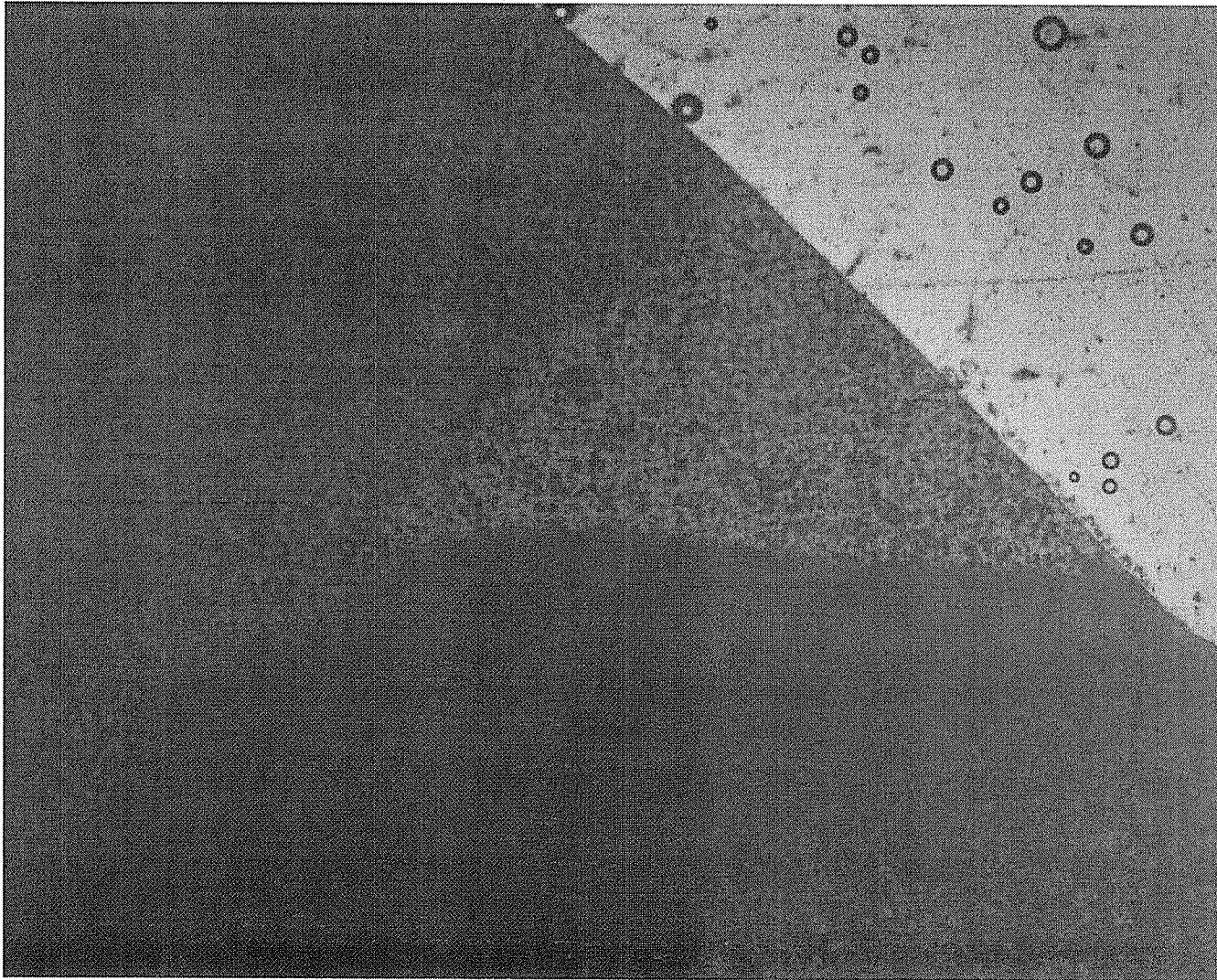


Figure D.18 S16 thin section sample, 4X magnification

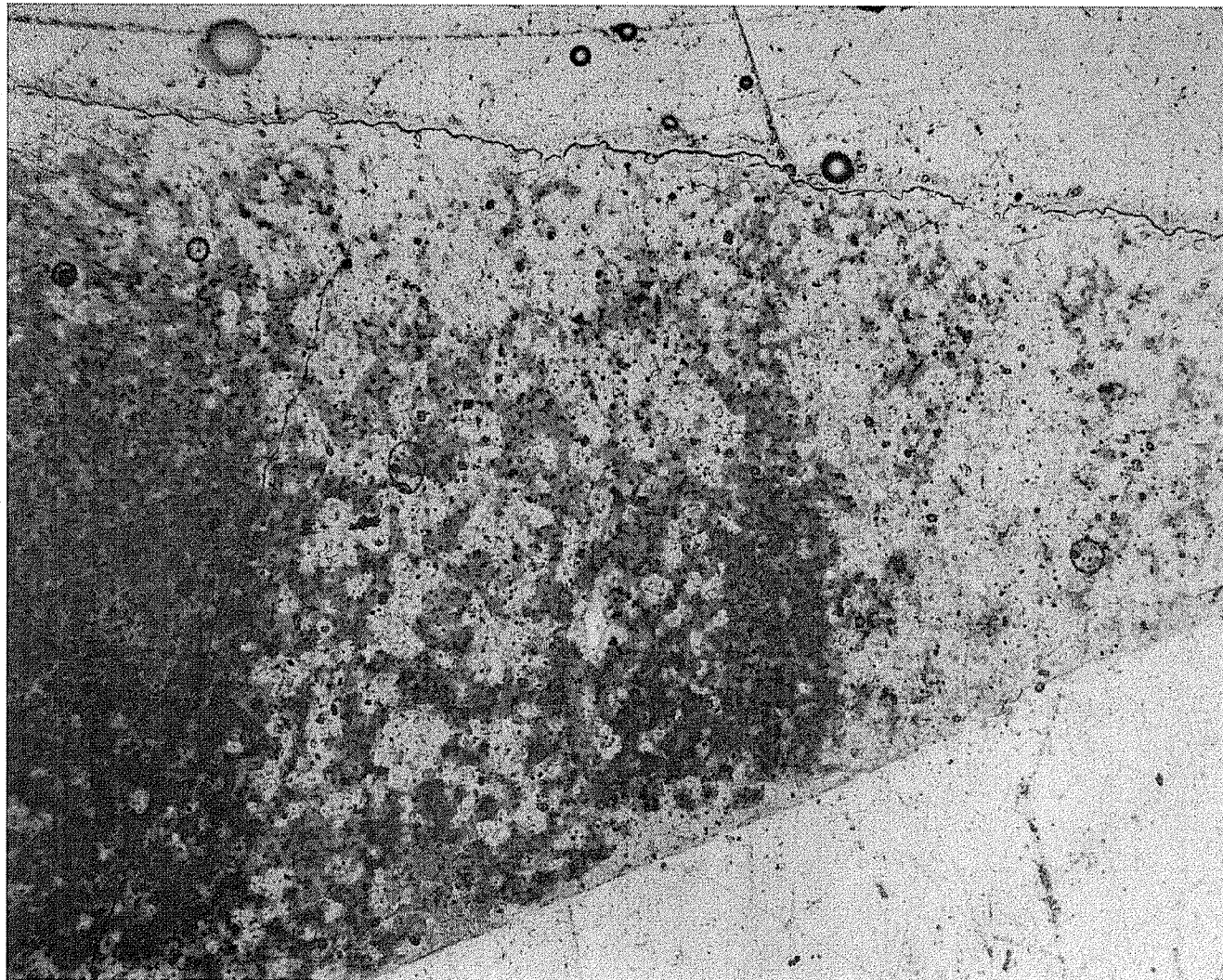


Figure D.19 S18 thin section sample, 4X magnification



Figure D.20 S20 thin section sample, 10X magnification

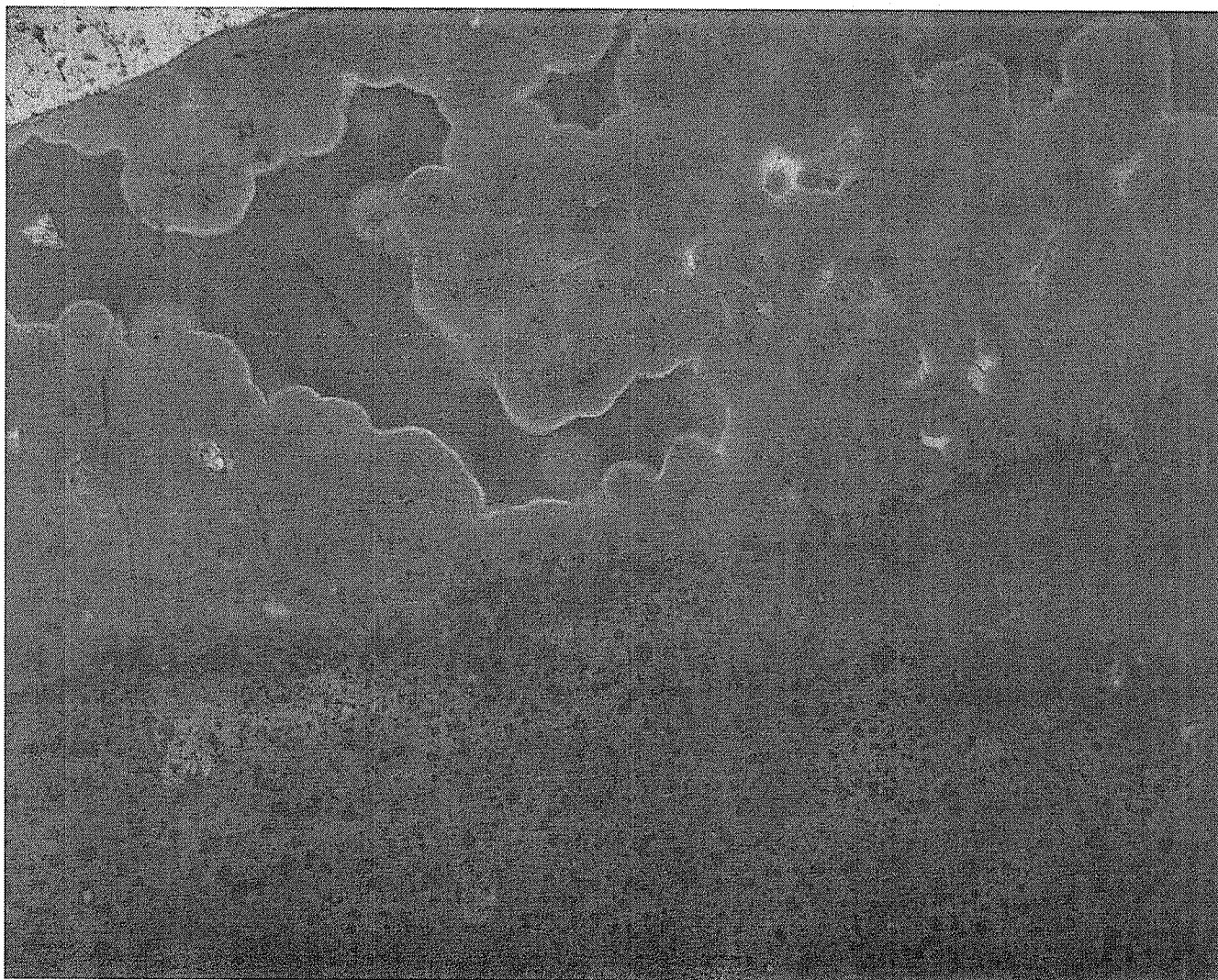


Figure D.21 S21 thin section sample, 4X magnification

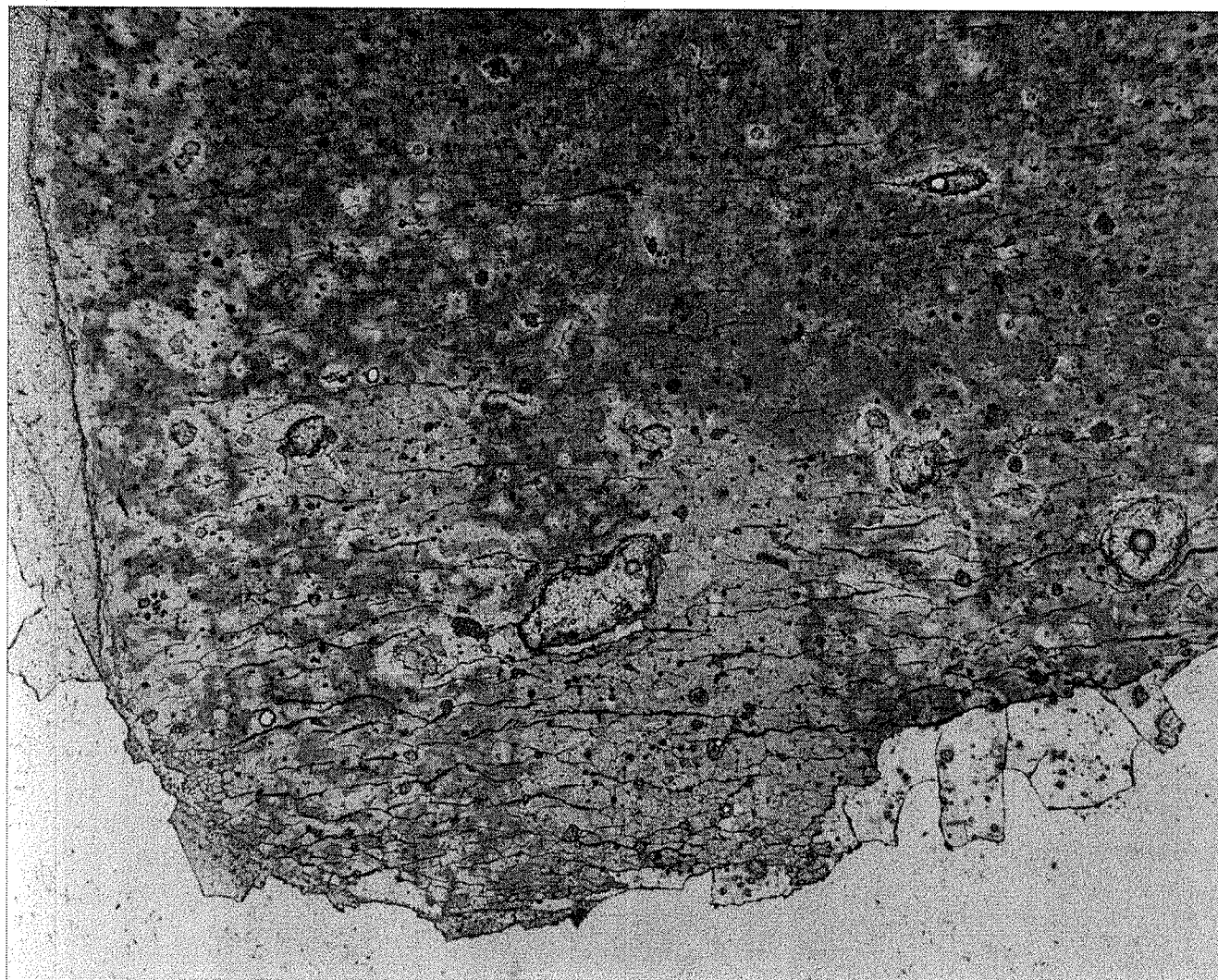


Figure D.22 S22 thin section sample, 4X magnification

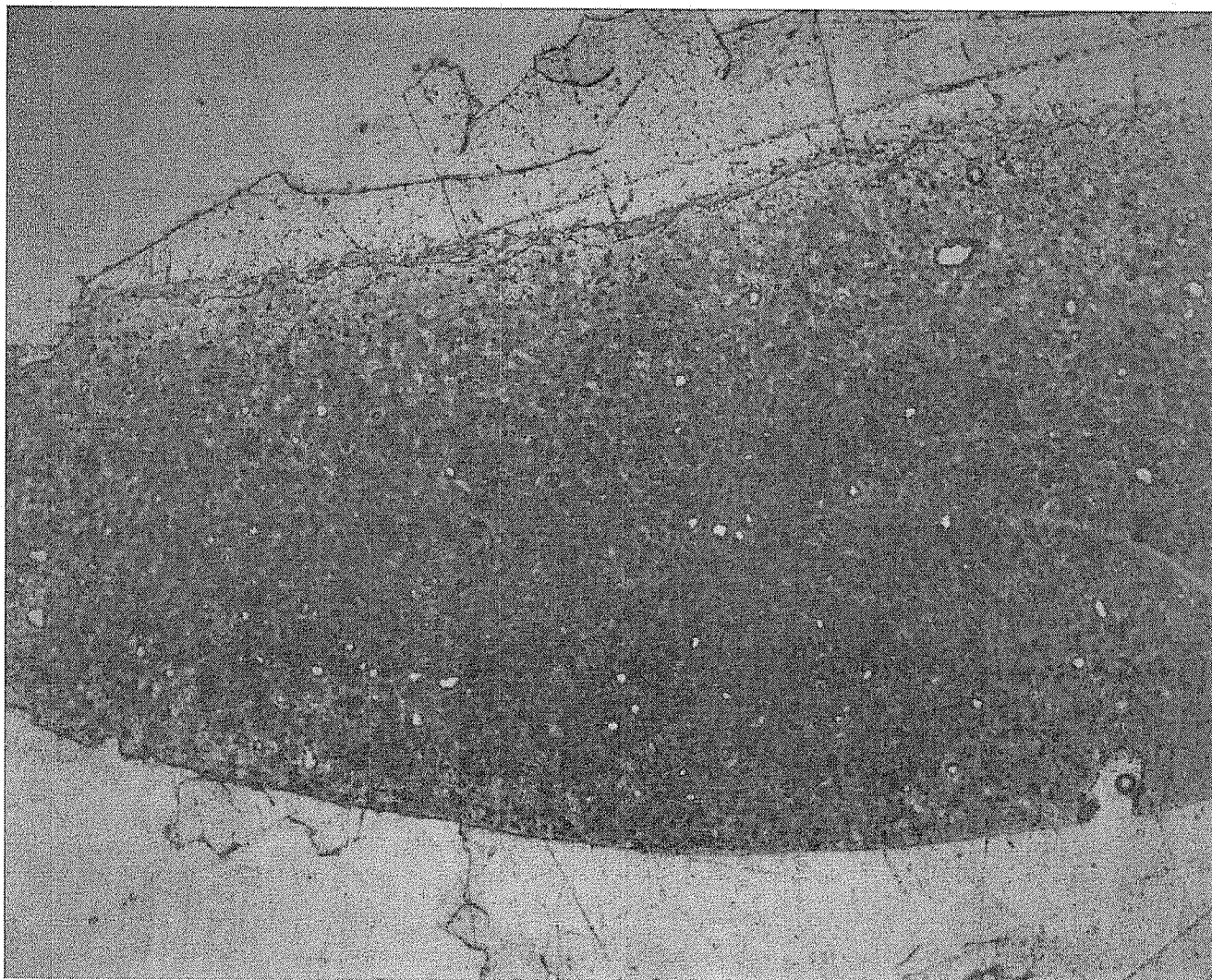


Figure D.23 S24 thin section sample, 4X magnification