THE ARCHAEOLOGY OF THE NANOOK SITE:
AN EXPLANATORY APPROACH
VOLUME I

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ABSTRACT

THE ARCHAEOLOGY OF THE NANOOK SITE:
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BY

Wendy Hanford Arundale

The Nanook Site (KdDq-9), a prehistoric Dorset site located on the south coast of Baffin Island, N.W.T., Canada, has a number of assets which made it intrinsically interesting to the archaeologist: 1) a relatively large sample of artifacts with good preservation of organic materials, 2) the presence of faunal remains, 3) radiocarbon dates which span a period of 500-600 years, and 4) the presence in the immediate vicinity of numerous other Pre-Dorset and Dorset sites to provide context and temporal control. However, to turn these interesting facts into a scientific study, it is necessary to ask pertinent questions, formulate problems, and test the hypotheses generated by these problems in an explicit and scientific manner. Two questions form the basis of this inquiry: 1) Why was the Nanook Site occupied periodically over such a long period of time without significant cultural change, and 2) Why was it finally abandoned? Answering these questions is the major goal of this dissertation.

To accomplish this goal in a manner which is fruitful not only for the present understanding of these problems, but also for future research in the archaeology of the eastern arctic, the models and methods employed are given explicit treatment throughout. A scientific paradigm

consisting of an explanatory model (the pattern model based on the Meehan System Paradigm (Meehan, 1968), two controlling models (Clarke's Ecological "paradigm" and Geographical "paradigm" (Clarke, 1972), and two operational models (an arctic ecosystem model and a general settlement pattern model) is implemented in the course of the explanation. Under the pattern model, explanation is accomplished when a loaded logical construct, called a system, is fitted to the data framed in terms of the concepts supplied by the controlling and operational models, called a description. This fit is accomplished by testing a series of hypotheses, and a major portion of this study is devoted to the discussion of the methods employed and the results achieved in testing these hypotheses.

Preparing the description necessary for loading and fitting the logical system, and fitting it to the data, requires information relating to the site's dates, to climatic change, to local climatic effects, to faunal resources, and to the character of the site itself. This information shows that on the basis of the radiocarbon dates, the Nanook Site probably was occupied periodically from approximately 2410 B.P. to 1827 B.P., a period of 583 years. While not all researchers agree on the climatic character of this period, it is clear that significant changes in the climatic regime of this part of the Canadian arctic took place toward the end of this temporal interval. A survey of pertinent evidence from a variety of palaeoclimatic sources, in conjunction with the standing wave model of climatic change derived from the analysis of more recent climatic events, indicates that prior to 1900 B.P. conditions at the Nanook Site were colder and dryer, while after 1900 B.P. they were warmer and wetter.

Such a fluctuation in climate could be expected to have a significant impact on the local ecosystem, including any human populations living in the area, because arctic ecosystems are quite simple, containing relatively few alternative energy paths. This structure subjects arctic ecosystems to strong control by the physical environment and leaves them highly vulnerable to the effects of climatic fluctuations. Thus, a fluctuation from colder, dryer to warmer, wetter climatic conditions would affect the two animal species which the faunal analysis reveals were major resources at the Nanook Site, the ringed seal and the caribou, making them less available to local Dorset hunters. Changes such as these must have constituted significant environmental changes for the human inhabitants of the area and would be expected to bring about adaptive responses on the part of the local Dorset culture.

To fit the description with the system (in this case, a logical calculus based on the work of Rice, 1975), and thus explain what adaptive response occurred and why, requires several hypotheses tests. These tests involve careful analysis of the radiocarbon dating problems, the fauna, and the artifacts using techniques ranging from literature search to statistical treatment including a cluster analysis approach. The results of these tests confirm that the Nanook Site was a Dorset site occupied periodically without significant cultural change from about 2410 - 1827 B.P. They indicate that the site was occupied during a relatively uniform climatic period, and did not undergo cultural change because climatic change, which would have affected the animal resources and brought about a human response, did not come about until approximately the time when site occupation ceased. However, the climatic change at about 1900 B.P. would have brought about animal resource population shifts which required settlement pattern change as a response. Abandonment of the Nanook Site location took place as a part of this response.

These results not only achieve the original goals of the study, but also have important implications for: 1) the value of the pattern model as an approach to explanation, 2) the structure of existing demographic models for the eastern arctic, particularly the Core Pulsation Model, 3) the choice of models of the underlying processes involved in climatic change, and 4) the manner in which future research in the eastern arctic is conducted.

THE ARCHAEOLOGY OF THE NANOOK SITE: AN EXPLANATORY APPROACH
Volume I

By

Wendy Hanford Arundale

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Reserved for last, but most important of all, are very special words of gratitude for Bob, who has chosen to bear with me the joys and trials of arctic field work, the frustrations of using the computer, the delights of intellectual discovery, and the challenge of maintaining humanity and personal growth in the midst of a long and often difficult research project.

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CHAPTER 1

INTRODUCTION TO THE PROBLEM

INTRODUCTION

The Nanook Site (KdDq-9) is a prehistoric Dorset Eskimo site on the south coast of Baffin Island, N.W.T., Canada. Several aspects of this site make it intrinsically interesting to archaeologists. Unlike many arctic sites, the Nanook Site has a comparatively large artifact sample. Preservation of organic materials, including both artifactual and faunal remains, is also unusually good for a site of its age. In addition, the site is stratified with radiocarbon dates indicating that it probably was occupied periodically over a 500 to 600 year time interval. Sites with similar time depth are rare in the arctic and present an unusual opportunity to study cultural continuity and change over time in one location. Such advantages for archaeological study are further enhanced by the fact that the site is located in an area where numerous other Pre-Dorset and Dorset sites spanning a period of nearly 3000 years have been investigated. These other sites provide additional temporal control, but more significantly, they supply a cultural context over time - - an important background against which the Nanook Site can be viewed.

The major investigative work establishing this 300 year sequence in the Lake Harbour area of southern Baffin Island has been done by M.S. Maxwell (1973) and his students. Maxwell concludes that these sites represent a clear-cut cultural continuum, as the artifactual evidence shows a marked lack of distinctive formal change, despite the exceptionally long time span involved. Maxwell points to Cleland's (1966) model of an adaptation characterized as a focal economy (one based on the specialized exploitation of one or a few plentiful resources, as opposed to the more generalized exploitation of a broad range of resources, known as a diffuse economy,) as appropriate for describing the pre-Thule economy of the Lake Harbour area. He feels that this type of economy enabled the Pre-Dorset and Dorset populations of this area to maintain a cultural "equilibrium" in the face of climatic change and other significant sources of variation in the natural environment. On the basis of the evidence from the Lake Harbour sequence, Maxwell suggests that this equilibrium was maintained by selective pressures for a changeless technology which were reinforced by strong ideational sanctions. Maxwell's inference that successful ecological adaptation has played an important role in the cultural continuity of the Lake Harbour area provides the foundation for this study of some of the questions and problems relating to the Nanook site.

The uncorrected radiocarbon dates for the Nanook Site indicate that the site was occupied from approximately 2410±120 B.P. (M-1535, Crane and Griffin, 1966) to 1827±61 B.P. (P-706, Stuckenrath _et al_, 1966), a period of 583 years. Although not all sources agree on the climatic character of this period, the literature on climatic change indicates fairly clearly that significant changes in the climatic regime of this part of the Canadian arctic took place toward the end of this temporal interval. More specifically, the initial occupation of the site began during a relatively cool, dry period. But by about 1900 B.P., it would appear that conditions had become noticeably

warmer and wetter in this part of the arctic. Such climatic change undoubtedly had an appreciable effect on the biophysical environment of the Dorset population, and in particular on the animal species which served as their food resources. A brief consideration of how such change affected these food resources will be helpful as a preface to the two major questions to be addressed in this study.

The climatic effects on the biophysical environment can be inferred both on the basis of general ecological principles, and by analogy with examples of the effects of climatic change documented during modern times. Utilizing the basic ecological concept of the food chain (Odum, 1963), for instance, it is apparent that arctic ecosystems were and are characterized by simple food chains and a limited number of food paths. Hence, the ecology of arctic species, including those which served as important resources for prehistoric human populations, would have been influenced quite directly by the changes in the physical environment brought on by climatic change. Likewise, modern data from the west coast of Greenland (Vibe, 1967), and other areas such as Iceland, over the past hundred years have provided vivid examples of how directly northern animal populations are affected by changes in climate. Although the specific climatic conditions of these areas differ in important ways from those of the south coast of Baffin Island, the data do illustrate the general proposition that comparatively minor climatic changes can bring about major shifts in northern faunal populations. A closer look at the actual processes involved for the caribou and ringed seal can illustrate the general points noted above.

Land mammal resources would have been more directly affected by the environmental changes brought on by climatic change than would sea mammal resources. Faunal analysis has shown the caribou, Rangifer tarandus groenlandicus, (Linneaus), to be the second most important animal resource at the Nanook site so that it is clearly the land mammal of greatest significance. Specifically, warmer, wetter conditions bring about more frequent ice crusts which make it difficult for caribou to forage. The deeper and sharper textured snow which results from warmer conditions also irritates the caribou's legs and makes their movement to obtain forage and evade predators more difficult. The length of the season when annoying insects are present is also extended by warmer, wetter weather. All three factors, icing of feeding areas, presence of deep, crusty snow, and annoyance of insects, have been shown to be significant in stimulating caribou movement away from areas in which these undesirable conditions occur (Kelsall, 1968; Pruitt, 1959a). Hence a warmer, wetter climatic regime could be expected to bring about a decrease in an area's caribou resources.

While the caribou was an important resource to Nanook Site residents, three lines of evidence converge to show that in terms of numbers and volume of meat, the ringed seal, Phoca hispida, (Schreber), was the most important animal resource for these Dorset hunters. First, the faunal evidence from the Nanook Site and from the nearby Morrison Site (KdDq-7-3) shows that a small phocid, probably the ringed seal, was the predominant resource being exploited at the time these sites were occupied. Geographic data show that the Nanook Site is well situated for exploitation of ringed seal, especially during

the period from late winter to early summer when the site is within reasonable proximity of the receding floe edge (Kemp, 1971). Second, while the ethnographic record is not necessarily representative of the past, it is interesting to note that the literature reveals a strong reliance on the ringed seal as a major resource in this area (Boas, 1964; Graburn, 1963; Kemp, 1971). And third, if all the potential food resources of the area are assessed, and if the whale, which it is agreed was generally not exploited until after the Dorset period, is excluded, it is clear that human subsistence in the site area would be difficult, if not impossible, without considerable reliance on the ringed seal.

Zoological research on the ringed seal shows how climatic change could affect this species. McLaren's studies (1958a&b) demonstrate that the size of the ringed seal population in a given area is heavily dependent on the extent and stability of the fast ice along the coast. Fast ice is the "apron" of ice which remains more or less attached to the shore during the late fall, winter and spring months. Areas with a smaller, less stable fast ice area have smaller ringed seal populations, and the individuals within those populations tend to be smaller in size. Because fast ice also provides a significant mode of access to the seal population for Eskimo hunters, and because ringed seals tend to disperse away from the near-shore areas during the open water season, the length of time during which fast ice is present during the year can have a significant effect on the availability of the ringed seal. Climatic factors such as an increase in temperature and rainfall, which decrease the overall area and stability of the fast ice as well as the length of time during the year when fast ice is present,

would therefore have the effect of decreasing the size of the ringed seal population available for hunting.

In addition to the effects of climatic change, the animal resource populations, particularly the land mammal populations, would be expected to undergo shorter term stochastic change. Factors such as parasitism, disease, and periodic fluctuations in the local availability of the food supply due to non-climatic causes, further enhance the variability of these animal populations beyond that induced by climatic change. Such variability adds a significant dimension to the environmental stress already present in the arctic environment.

Changes such as these in the animal populations which served as major resources for the Dorset population of the south coast of Baffin Island would constitute significant environmental changes for the human inhabitants and would be expected to bring about noticeable adaptive responses on the part of the Dorset culture in this area. If these adaptive changes in the culture took place, evidence of their occurrence should appear in the archaeological record. Yet the Nanook site was occupied for 500-600 years without significant variation in the kinds or proportions of artifacts which occur there (Arundale, 1971; Maxwell, 1973). This situation constitutes a marked contradiction of the pattern one would expect in an area where the culture is finely tuned to environmental constraints, and where the non-human environment is subject to considerable variation. Thus, the first major question which the Nanook site evokes is: Why was the site occupied periodically over such a long interval of time without significant cultural change? Answering this question is the first major goal of the dissertation. However, this absence of cultural change is not the only aspect of the site which constitutes a contradiction of one's expectations. If the people who periodically occupied the site were well enough adapted to live for 500 years in such a highly variable environment, without showing significant evidence of cultural change, then: What finally caused them to abandon the Nanook location as a settlement site? Accordingly, the second major goal of the dissertation is to explain why the Nanook Site was finally abandoned.

THE PARADIGM AND ITS CONSTITUENT MODELS

In order to accomplish these two goals in a manner which will be fruitful not only for the present understanding of these problems, but also for future research in this area, the models and methods employed herein will be given explicit treatment throughout. An attempt will be made to avoid polemic, but at the same time to justify the approaches and strategy chosen on the basis of their potential for providing useful and productive solutions to the problems at hand.

Whether or not an investigator recognizes it, all research is conducted in the context of a paradigm, a specific methodology composed of a set of beliefs, values, methods and techniques concerning both the subject matter of a given discipline, and how research on the subject matter should be conducted (Kuhn, 1970a). There are three major constituent elements of the paradigm employed in this research, and a diagram relating these three elements appears as Figure 1. The first of these elements is the explanatory model. Such a model is usually a reconstruction of the logical processes used successfully

Problems:

1) Why was the Nanook site occupied periodically for 500-600 years without significant change?

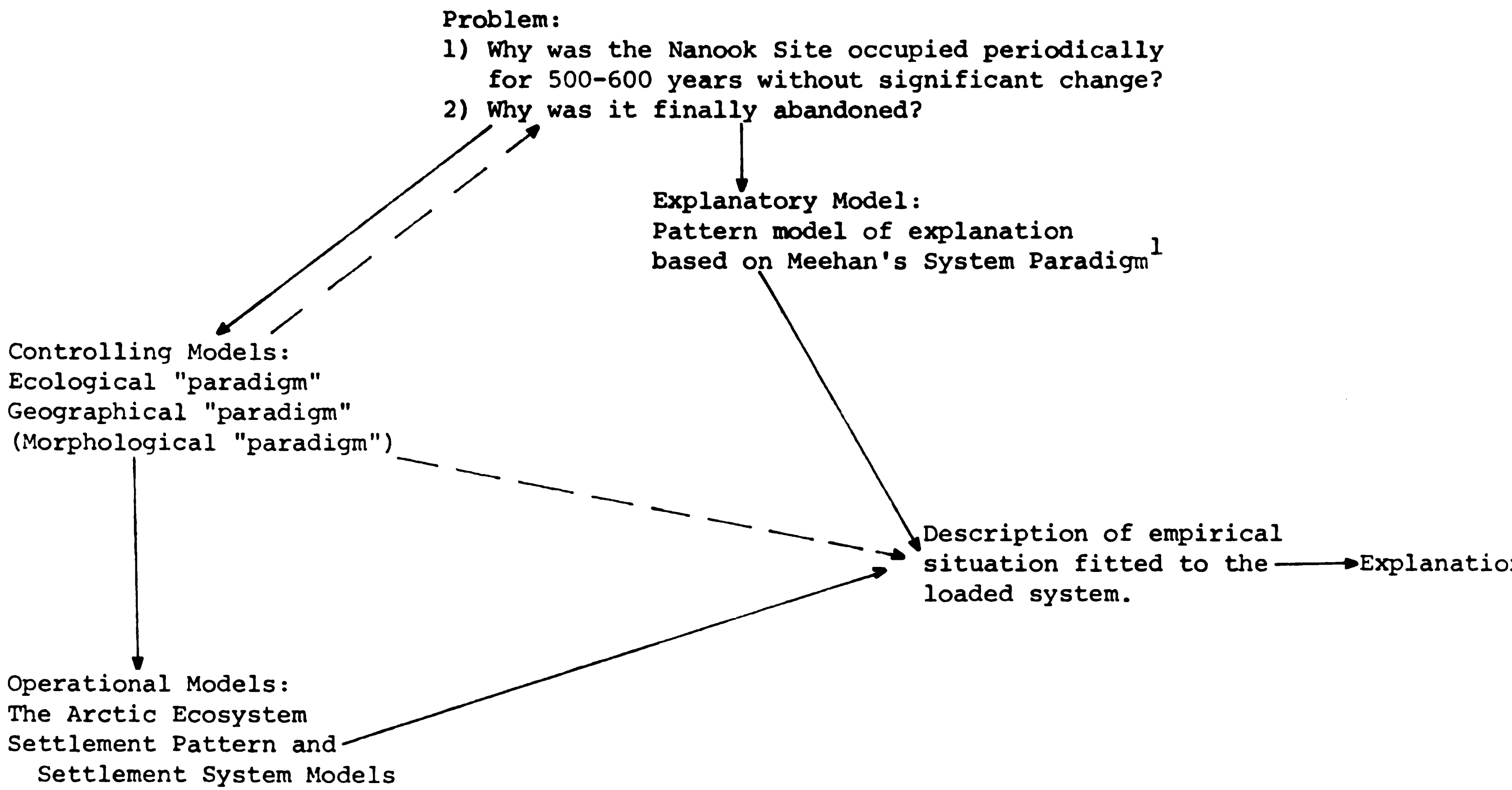

Figure 1. The relationship between the problem and the models which form the paradigm.

for problem-solving in many different fields of scientific endeavor. The second element is the controlling model (or models). Controlling models are:

> embodied in the archaeologist's philosophy, the paradigms he chooses to align himself with, the methodologies he finds most congenial and the aims that this system constrains. (Clarke, 1972:5)

Controlling models are generally subtle and sometimes relatively obscure, however they are extremely important because they affect the researcher's selection of operational models, the third element. Operational models are those:

> which the archaeologist consciously and deliberately deploys ...(they are)...the experimental analogues or the hypotheses produced from them, which the archaeologist pushes against a sample of archaeological reality to test the goodness of fit between the two. (Clarke, 1972:10)

The explanatory model employed in this study is drawn from the work of Meehan (1968) and can be broadly characterized as a patterning approach to explanation (Kaplan, 1964). Very briefly, Meehan's model is based on the construction of a formal explanatory system, including variables and rules linking those variables, which is then "loaded" with terms and concepts from the real world situation under investigation. Explanation is accomplished by linking the loaded formal system with a description of the phenomena to be explained by a series of hypotheses. A discussion of this explanatory model, together with a description of its operation and the rationale for its selection, will form the major elements of Chapter 2.

Controlling models, which are perhaps the most difficult to ferret out and make explicit, will be dealt with in Chapter 3. Two of the newer controlling models which Clarke (1972) discusses, namely the Ecological "paradigm"[2] and the Geographical "paradigm", have played important and closely related roles in shaping the choice of models and methods made herein. A third controlling model, the Morphological "paradigm" has made an important contribution to the models.

In turn, these controlling models have influenced the choice of operational models. These models, which are also discussed in Chapter 3, are used in Chapter 4 to shape both the description of the data and the loading and fitting of the logical system which form the basis for explanation. Two closely interrelated operational models, one drawn from each controlling model, are used in attempting to explain the long, unvarying occupation of the site, followed by its abandonment. The first model provides an insight into the nature of the Arctic Ecosystem and the manner in which it is subject to strong perturbations. Because it is a relatively unstable system, sources of variability such as climatic change can bring about startling alterations in the availability of animal populations which serve as human resources. The second model provides the concepts of settlement pattern and settlement system, two concepts very useful for detecting a human response to resource change in the archaeological data. These two models will serve as the basis for loading the formal system which provides the framework for explanation in the Meehan approach.

Chapter 4 is divided into two major sections. The first is the description of the empirical situation, couched in terms of the relevant concepts from the controlling and operational models. The description is further subdivided into five parts, one each on the dating of the site, general climatic change, the local effects of climatic change, the response of animal resource populations, and a general description of the site. The second section of Chapter 4

consists of the formal structure of the logical system, the loading of that structure with the concepts, and the hypotheses for fitting that structure with the description.

Chapter 5 which deals with the hypotheses for fitting the system also has two sections. In the section dealing with Methods and their Implementation, the methods for three areas of analysis are presented: radiocarbon dating, faunal analysis and artifactual analysis. This section is followed by a Results Section which discusses the results of each test of the hypotheses.

The final chapter summarizes the results of the tests, drawing final conclusions, and then discusses the implications of the results for broader areas of concern within arctic archaeology.

THE SIGNIFICANCE OF THE RESEARCH

In addition to outlining the goals of the study and the manner in which this research will be pursued, it is important to discuss its significance. There are several important reasons for doing this study. First, this research deals with the basic question of the relationship between a culture and the biophysical environment in which it exists, and how changes in that environment affect the culture. These are basic questions in archaeology today. Because most Dorset cultural entities probably did not have to contend with the adaptive constraints imposed by the presence of other human groups possessing a different culture, they represent an unusual situation in which the relationship between environment and culture can be studied apart from the interference of other variables. In addition, our present understanding of the particular relationship between Dorset

culture and the resources which it exploited is extremely limited. This study represents one of the few specific cases in which that relationship is being explored.

Second, recent conceptual schemes concerned with the development and the relationships within Dorset culture have made a distinction between events in the "core area" and events in the "marginal areas" with respect to climatic change (Dekin, 1974, 1975; Fitzhugh, 1973, 1974; Maxwell, 1973). This study will provide an opportunity to examine some of the propositions advanced by these conceptual schemes in the light of a specific case from the "core area."

Third, recent arctic studies involving the effect of climatic change have made the presumption that warmer climatic periods were generally more favorable to increased resources and probably to larger human populations (Dekin, 1975; McGhee, 1972). This study indicates that such a presumption may be true for some parts of the arctic at some times, but that at other locations or during other periods, it may not be the case. This study is significant because it points out the difficulties in this broad generalization. It presents climatological and biological evidence which supports the opposite generalization: warmer, wetter conditions would seem to produce a reduction in some resource populations, and it shows the necessity of knowing the local situation through its examination of a locality where this opposite generalization holds. Because the known arctic sites constitute a very small sample, the probability that these sites are representative of the population is not high. The results of this study suggest that it is very important to understand the specific ological ar

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ecological and geographical circumstances of individual arctic sites before generalizations are made concerning broad climatic effects.

Fourth, while the goals of this research are highly idiographic, this study has implications for several broader issues, the investigation of which will require not only some new conceptual apparatus, but also some significant changes in the methods and techniques arctic researchers employ. These broader issues include, for example, the need to learn a great deal more about Dorset subsistence-settlement systems and how these systems responded to variation in the biophysical environment, as well as the need to learn more about human populations living in small, relatively isolated groups and how such populations respond to situations where population growth is not permitted or even where population diminishment is required.

Finally, this study is one of the few investigations in arctic archaeology that attempts to use an explicit, hypothesis-testing, explanatory approach. Because the arctic is a large area about which relatively little is known, until very recently archaeologists have focused much of their attention on the discovery and description of sites and assemblages. Although the most recent eastern arctic literature has moved away from description toward the formulation of fruitful conceptual schemes, very few of these contributions propose an explanatory model, derive hypotheses, or test these hypotheses in an explanatory fashion. Specifically, this research will attempt to illustrate the value of using a general scientific research paradigm in which an explanatory model originated by Meehan (1968) structures the explanation process. No claim is made that this approach constitutes <u>the</u> way arctic research should be conducted. However, there is xplicit a

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an explicit attempt to justify this strategy, in terms of its greater potential not only for producing useful information for this project, but also for providing a valuable starting point for future research.

NOTES

1. In this instance, Meehan uses the term "paradigm" to denote a particular explanatory model rather than to denote a set of beliefs, values, methods and techniques. Again, see Chapter 2, page 25 for further discussion of the paradigm concept.

2. Clarke is using the term paradigm to denote a particular class of controlling models rather than to denote a set of beliefs, values, methods, and techniques. See Chapter 2, page 25 for further discussion of the paradigm concept.

CHAPTER 2

THE EXPLANATORY MODEL

INTRODUCTION

In his recent dissertation, Models of Pre-Dorset Culture: Towards an Explicit Methodology, Albert A. Dekin, Jr. (1975) has focused on a number of current methodological, theoretical and conceptual problems in arctic archaeology. Faced with the necessity of using data from the literature to test two of his three models, Dekin encountered a number of difficulties because the specifics of what various investigators had done and why was not apparent from their reports. The differences which Dekin and others have encountered in archaeological interpretations are the result of several sources of variation. As Dekin has listed them, they include:

> 1) variations in the data under consideration (including differences in the techniques of recovery, depiction and categorization); 2) variations in the methods of analysis applied to the data; 3) variations in the paradigm which each investigator brings to the data, and analysis; 4) idiosyncratic phenomena characteristic of the archaeologist (personality, intellect, and experience, for example); and 5) the history of past variations in interpretations. (Dekin, 1975:304)

Sources 1, 2 and 3, at least, can be clearly specified if the researcher chooses to do so. Yet in the arctic literature, the reader is frequently forced to search for hidden clues as to the assumptions made in any given piece of research, a time-consuming and potentially unreliable process. Accordingly, a researcher must work with a potentially unreliable guess about another investigator's choices of data, analytical methods, and research paradigm. By the taken,

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same token, these choices are not available for discussion and evaluation by other members of the discipline. Thus, Dekin found that a basic lack of precision and explicitness concerning these sources of variation lay at the heart of many of the problems he encountered (Dekin, 1975:1).

PARADIGMS AND ARCTIC RESEARCH

Elaborating further on the problems which have beset much of the research conducted in the arctic, Dekin (1975:305-306) notes that little of the current discipline-wide debate over the paradigm under which research is conducted has had any impact on arctic work. There is no explicit discussion of why a given problem is worth studying or why a given set of field data is worth using. Many investigators have just assumed that the main goal of arctic research is the development of a space-time framework. The "prevailing paradigm" in much arctic research must therefore be ferreted out of scattered statements in a variety of different sources. This paradigm has an implicit, essentially empiricist orientation in which research has been conducted in an inductive, or at least data-centered, rather than in a basically deductive manner. The major set of assumptions or implicit theory which have guided the operation of this paradigm can be characterized as the 'guide fossil' or 'type fossil' approach. Until Dekin's dissertation, this prevailing paradigm has seldom been explicitly stated or discussed by arctic specialists and even more rarely questioned.

Yet archaeologists doing research outside the arctic began to deal with similar problems more than ten years ago. The "traditional paradigm" (Swartz, 1967; Thompson, 1958) a category into which the arctic's prevailing paradigm clearly fits, has been the subject of ongoing discussion and criticism for some time (see, for example, Fritz and Plog, 1971; Hill, 1972; Binford, 1968, 1972: Watson *et al.*, 1971). Why has it taken arctic researchers so long to begin this much needed self-examination and debate, and why has it finally begun now? To answer these questions, it is necessary to look briefly at some of the events taking place in arctic work. Some of the reasons why discussion has finally begun would appear to be very similar to those which originally stimulated archaeology as a whole to move in this direction, and like the discipline as a whole, there is probably no single cause which is responsible for the development of such discussions. Arctic research has merely been somewhat slower to reach the point where these problems demanded attention. Some of the factors which have motivated discussion of paradigmatic issues are these:

1) *The growing inadequacy of personal information networks* (Plog, 1973). Unlike the case of many other geographic areas, the number of researchers has remained relatively small and a great deal of information is still communicated through personal networks. For example, in 1973, Maxwell was able to gather together a majority of the researchers working on Pre-Dorset and Dorset problems at a seminar which included only eleven participants (Maxwell, in press). Some communication breakdown is beginning to occur however, for not all younger workers find themselves included in the information network, and as the number of people and the amount of information grows, this problem will become more acute.

2) <u>The realization, with an increasing number of regional comparisons, that techniques of recovery and analysis have not been consistent</u> (Plog, 1973). Problems demanding extensive regional comparisons of the kind which would point up such inconsistencies are very new in arctic research. While Collins (1953) and others have conducted regional comparisons, some of which go back to the very beginning of arctic research, their primary goal has been to develop a space-time framework for the arctic. The relatively small number of known sites spread out over such a large area, together with the 'guide fossil' assumptions under which they operated, caused most workers, implicitly or explicitly, to attribute much of the uncontrolled variability they encountered to the fact that there were as yet so many large unknown areas. However, as a few areas become known in greater depth (for example, the Lake Harbour area of Baffin Island and Hamilton Inlet, Labrador), and as more of the unknown areas are explored, it is becoming increasingly clear, as Dekin points out, that differences in recovery and analysis techniques have a marked effect on the variation observed.

3) <u>The recognition that existing paradigms are not adequate to solve a growing number of problems</u> (Sterud, 1973). The increased variability observed as a result of more concentrated studies of particular local areas, and of increased exploration of unknown areas cannot be explained entirely by the historical change factors which have long served as the basis of most arctic research. Very recently, this new data has led to the examination of new problems. Studies involving a consideration of settlement patterns (Harp, 1973; Fitzhugh, 1972), of the role of climatic change (McGhee, 1972; Dekin, 1969, 1960, 1971,

1972, 1974, 1975; Fitzhugh, 1972, 1973a&b, 1974), of demographic change (Dekin, 1975; Fitzhugh, 1973b, 1974) and of questions of social organization (Dekin, 1973, 1975) are beginning to be published. The prevailing paradigm, which Dekin describes, is aimed at solving a very different problem, namely the delineation of spatial/temporal sequences. However, because consideration of these newer problems is very recent, the inadequacy of the prevailing paradigm is only now being perceived.

4) Increased contact with other disciplines where scientific, theoretical and operational procedures are more entrenched (Plog, 1973). The need for arctic researchers to have extensive contact with other disciplines such a climatology, ecology, oceanography, and quaternary studies has become apparent only with the advent of the new problem areas such as those mentioned above. Even though this contact may well broaden the paradigmatic and methodological perspectives of arctic specialists, the paradigmatic debate which has been going on for nearly ten years in archaeology as a whole is likely to have considerably more influence than other disciplines in this regard.

5) Change in the reasons for conducting research and in the institutional frameworks in which it takes place. Until now, most eastern arctic research has been conducted by investigators from the National Museum of Canada, the Danish National Museum, the Smithsonian Institution, or from one of the small number of universities in Canada and the United States. These institutions have sponsored research almost entirely within a scholarly context. However, as the demands for commercial exploitation of the arctic grow (see, for example, Morehouse, 1975), the role of archaeological resource assessment and salvage is likely to grow, as well. The great increase in both

personnel and information already made in connection with the Alaskan oil pipeline are indicative of the kind of future challenges researchers in the eastern arctic may soon face. Although not as directly related to the paradigmatic debate as the other factors listed, salvage archaeology has had a marked impact on the scope and conduct of archaeology generally (Binford et al., 1970; Gummerman, 1973; King, 1971; Struever, 1968a). It is difficult to believe that a similar impact will not be felt eventually in the arctic.

Under the influence of forces such as these, some informal discussion of the problems associated with the prevailing paradigm have taken place among arctic investigators. However, Dekin's dissertation is one of the first publications to deal specifically with these issues. In order to remedy the problems he sees, Dekin proposes a new strategy for arctic research. The basis for this new strategy is the premise that, "The study of archaeology is first and foremost the study of past human behavior, using essentially artifactual evidence (Dekin, 1975:308)." Dekin views human behavior as resulting from multiple causes. Thus, the fundamental strategy of our discipline should be the partitioning of variation in human behavior, much as statistical techniques such as analysis of variance partition variance in a sample. Dekin also argues that archaeologists should not assume a priori that all variation in human behavior results from cultural activities, since such an assumption would be tautological.

To implement this strategy, Dekin advocates the development and testing of models of human behavior using Chamberlain's (1965) "method of multiple working hypotheses." This method must be utilized within

a framework in which the working hypotheses are viewed not as mutually exclusive, competing alternatives, but rather as proposed sources of variance, each of which may contribute to the variations in the observed behavior which is the focus of our research (Dekin, 1975: 308)." Above all, Dekin feels that there is a crying need for precision and explicitness[1] in all aspects of arctic research. He presents his study as an example of the explicit use of models and methods and sees such studies as ultimately leading to the generation of non-trivial hypotheses and laws.

The proposals embodied in Dekin's new strategy represent some major steps forward in arctic research methodology. At this point in the development of arctic research, three aspects of his strategy seem especially significant. First, his comments appear to represent the first critical self-examination in eastern arctic archaeology. The capacity for constructive self-criticism and self-correction is an indication of increasing maturity in a discipline, and is a quality which can be of significant benefit. Self-criticism and self-correction can lead to an end to what Dekin has called 'mindless' research: research conducted without serious consideration of purpose and without a questioning of established practice (Dekin, 1975:307). An increased self-consciousness about the work being done can ultimately lead to a marked improvement in the value of the information gained from arctic research. Such criticism cannot include vitriolic, ad hominem attacks on fellow scholars, but rather must focus on healthy, constructive critical evaluation of current work, a phenomena now curiously lacking in much arctic work.

Second, Dekin's strategy is significant in that he advocates a precise, explicit scientific approach involving the formulation of models and the testing of alternative hypotheses. Although some eastern arctic researchers have recently begun formulating their ideas in terms of explicit models, Dekin is the first to emphasize the need not only for the clear presentation of such models, but also for the testing of such models in a scientific manner, through the explicit statement of hypotheses and delineation of methods, and the precise execution of tests and presentation of results.

In advocating this new strategy for arctic research, Dekin has drawn on a number of the ideas which have been generated in the current debate in the discipline as a whole. As Dekin has done, other arctic workers might find it advantageous to join in the current discussions, taking from them the more useful and constructive results of the debate, and leaving behind the more destructive and non-productive ones. By urging arctic researchers to involve themselves in the current paradigmatic debate, however, this investigator is not advocating that all investigators in arctic archaeology embrace one specific approach to research which would thereby solve all methodological problems. For if one issue has been made clear in the current debate in archaeology, it is the principle that no one approach is suitable for solving all problems at all times. As Kaplan has cleverly put it, "There is more than one way to skin a cat, and the family Felidae has some remarkable specimens (1964:9)." Though some members of the archaeological community have stridently advocated one approach or another (for example, Watson, 1973b; Watson et al., 1971; Hawkes, 1968) it is clear that each has its limitations.

Instead, our objective should be to select the approach (1) which is most suitable for our problem, (2) which can be employed successfully given the state of the discipline at the present time, and (3) whose limitations, given 1 and 2, will prove most innocuous while making the greatest contribution toward advancing our knowledge. In other words, we must choose the approach with the greatest payoff (Chartkoff, 1972; Morgan, 1973; Platt, 1964). In retrospect, when the goal of arctic prehistory was the delineation of a space-time framework, the implicit, empiricist orientation of the traditional paradigm proved to be a workable approach. However, as the goals of arctic researchers change, shifting away from the past emphasis on culture history, this older paradigm has proven to be inadequate, as Dekin has shown.

This emphasis on goals and on the relative payoffs of different approaches leads to the third significant aspect of Dekin's strategy. While Dekin has made some strong statements about the directions in which arctic research should go, the general constraints he establishes leave ample opportunity for researchers to adopt a broad range of more specific approaches. The basic constraints he establishes for research are:

1. Overt consideration of the purpose of any proposed research.
2. Explicit and precise statement of the models, methods, tests, and results which are included in the research, so that critical evaluation by other investigators can take place.
3. Use of a hypothesis testing framework to test the proposed models, and specifically the use of multiple hypotheses which are not necessarily mutually exclusive.

4. Careful and precise definition and use of concepts, in particular the concept of culture, so that tautological assumptions about the causes of human behavior are avoided.

Such a broad set of constraints on the choice of approaches has a number of advantages for arctic archaeology at this time. First, it embodies those qualities which other behavioral scientists see as the basic characteristics of scientific research:

> Scientific research is systematic, controlled, empirical and critical investigation of hypothetical propositions about the presumed relations among natural phenomena. (Kerlinger, 1964:13)

Thus, by specifying a set of constraints which should be applied to the constituent elements in any approach used to solve arctic problems, Dekin has essentially delineated the outlines of _a_, but not _the_, general scientific paradigm for archaeological research.

Second, within the framework of this approach a researcher may pursue a number of different, more specific strategies in order to most effectively accommodate the new and rapidly changing problems of interest in the field. Third, Dekin's constraints avoid the dogmatic assertion that there is only one way to conduct successful arctic research, and thereby obviate some of the less productive aspects of the current paradigmatic debate. Fourth, and finally, these constraints still embody some badly needed changes which will make the results of arctic archaeology more open to discussion, evaluation and use by others, and thereby make the efforts of researchers in this field more productive.

BASIC CONCEPTS IN THE PRESENT APPROACH

Paradigm. At this point in the discussion, it is useful to pause to examine some of the concepts which underlie the discussion in this chapter, specifically the terms paradigm, explanation, logic-in-use vs. reconstructed logic, deductive model vs. pattern model of explanation. The term paradigm has been used a great deal in recent discussion in archaeology (for example, Fritz and Plog, 1971; Hill, 1972; Sterud, 1973). The term has taken on a broad range of meaning in these discussions.

> A paradigm is a theory or set of propositions assumed or known to govern the operation of an isolated body of phenomena. A paradigm is as simple as the rule for conjugating a verb or as complex as a theology. In science, a paradigm is the consistent and all but universally agreed-upon way in which, for example, the physical, biological, or economic worlds are supposed to be governed. Such views are those invented by Einstein for physics, the synthetic theory of evolution in biology, and neo-Keynesian economics. (Leone, 1972: 15)

For the purposes of this study, however, it is useful to narrow this definition to two more precise meanings.[2] The first meaning for paradigm is "the entire constellation of beliefs, values, techniques, and so on shared by the members of a given scientific community (Kuhn, 1970a:175)." The second meaning denotes the exemplary achievement in science, the concrete puzzle solution which can serve as an ideal pattern for the solution of other, similar puzzles (Kuhn, 1970a:75). "Paradigm" in this second sense has been used to indicate both A) the exemplary or prototypic solution itself, and B) an abstraction of the essential steps or dimensions of the exemplary solution. This abstraction generally depicts the more complex process of solution in

somewhat condensed or simplified terms. In what follows "paradigm" will be reserved for A), while the term "model" will indicate the usage denoted in B).[3]

In the recent archaeological literature, both meanings of paradigm have been employed. For example, when Hill (1972) discusses the "traditional paradigm" in archaeology, he is using the term in the first sense. However, when Clarke (1972) cites the work of Coe and Flannery (1964, 1967) and MacNeish (1961, 1962) as examples of the ecological paradigm in modern archaeology, he is using paradigm in the second sense. Sometimes the two senses of the word are blurred, or paradigm is used instead of the term model, making it difficult to discern exactly what is intended. In general, when the term paradigm is used in this study, the first meaning is denoted. On those occasions where the second meaning is used, this meaning will be specifically indicated. The major exception to this practice will be in the specific phrase, "Meehan's System Paradigm", where the word paradigm refers to an explanatory model. Although Meehan (1968) has adopted the word paradigm, the term model is in more accurate agreement with the terminology established for this study.

The concept of a paradigm in the first sense has become common in archaeological parlance largely because several archaeologists have become interested in Kuhn's model of how scientific disciplines develop and change. These individuals do not agree as to where in Kuhn's broad scheme of change the infant science of archaeology presently fits. Some such as Fitting (1973), view archaeology's state as "preparadigmatic", a period in which a number of viewpoints and interests, each with its own observational specialty and theoretical orientation, compete. Others such as Dekin (1975), see archaeology as in the midst of a period of revolution between an earlier paradigm, "the traditional paradigm", and a new paradigm which has not yet completely emerged, but which embodies many of the characteristics of the general scientific paradigm outlined above.

Indeed, some of the archaeologists who have referred to the Kuhn model imply that a rigidly scientific paradigm, based on the deductive nomological model of explanation will be the emerging new paradigm in archaeology (Watson et al., 1971 for example). There is a danger, of course, that these implications will become a self-fulfilling prophecy, and several workers have recently spoken out in support of the value of a variety of paradigms and models for archaeology (Clarke, 1972; Thompson, 1972; Trigger, 1973; Watson, 1973a) "as a condition of archaeology's continuing viability (Adams, 1973:321)."

It is important to recognize, as well, that Kuhn's model of scientific change, like any model has inherent dangers and potential shortcomings. A major portion of Kuhn's training is in physics (Kuhn, 1970a), and his model draws heavily on that field. Is a model based so extensively on a science which includes several classical "finished" theoretical systems a good model to apply to a very new and "unfinished" science such as archaeology? Before archaeologists allow Kuhn's model to become a "ruling hypothesis," they should look at other possibilities.[4]

Kuhn's model aside, however, the concept of a paradigm becomes very useful when various approaches in archaeology are being evaluated for their "payoff potential". The concept of a paradigm provides a framework within which one can analyze any approach in terms of certain constituent elements: its explanatory models, its controlling models, and its operational models. For example, the traditional paradigm in archaeology involves an explanatory model based on the logical process of induction, a controlling model which is primarily historical in nature, and a very limited set of operational models, namely those depicting the processes of diffusion and migration. It was the limitations of the historical controlling model (Steward and Setzler, 1938; Taylor, 1967) and the inadequate repertoire of operational models which sparked the initial criticism of the traditional paradigm. Yet, even if more broad-ranging controlling and operational models are substituted, it is the non-scientific, inductive explanatory model[5] which is currently the most significant obstacle to efficient, productive archaeological research, both in the discipline in general, and in arctic archaeology, in particular.

Explanation. The key position of the explanatory model in any paradigm, as well as the significance of its limitations, can be more clearly understood by examining first the definition and then the role of explanation in science. The concept of "an explanation" has a variety of meanings, only a few of which are relevant to this discussion. One useful and general definition which covers all forms of explanation is "a process by which a private understanding is made part of public knowledge (Hammell, 1968:157 cited by Rice, 1975:5)." There are many specific kinds of explanations such as historical explanations which account for a unique sequence of events in history, or religious explanations which explain by reference to some article of faith (Rice, 1975:5-6). Effective explanation involves "not just coming up with or developing a clever idea but ... also getting others to see or experience a discussion of 'an answer' or 'a problem' in the same way (Chaney, 1972:992)."

In this research, the concern is exclusively with scientific explanations, explanations which involve an attempt to go beyond mere authority to explanatory systems which coordinate observation and experience, and which are open to examination by others. "The essence of science in contrast to other ways of knowing is that it attempts to be self corrective (Chaney, 1972:992)." Thus, the factors which distinguish a scientific explanation from others lie primarily in the manner in which the private understanding is made public (Rice, 1975: 6).

It is difficult, however, to find a satisfactory definition of scientific explanation which is not tied to a particular explanatory model. And just as there is no single paradigm or approach which is suitable for solving all problems at all times, there also is no single explanatory model which can be designated the scientific method (Kaplan, 1964:8; Morgan, 1973). Because of this difficulty, it is worthwhile to examine two separate definitions of scientific explanation. Hammell (1968:158) sees the significant aspect of the process of scientific explanation as "proceeding to a higher level, referring to that class of which the explanandum (thing or event to be explained) is a member (cited by Rice, 1975:6)." This definition seems particularly relevant to what will be discussed below as the deductive model of explanation. Kaplan on the other hand, sets forth the following definition of scientific explanation:

> An explanation may also be said to be a concatenated description. It does its work, not by invoking something beyond what might be described, but by putting one fact or law into relation with others. Because of the concatenation, each element of what is being described shines, as it were, with light reflected from all others; it is because they come to a common focus that together they throw light on what is being explained (Kaplan, 1964:329).

Kaplan's definition of scientific explanation is especially relevant to the pattern model of explanation which will also be discussed below. Kaplan further distinguishes a scientific explanation from an explanation of meaning (a semantic explanation, in Kaplan's terms) by drawing a parallel to the contrast between a true statement and a clear statement. A semantic explanation possesses only clarity; it is meaningful only to a given audience. A scientific explanation possesses a truth based on logic; it exists whether or not anyone accepts or understands it (Kaplan, 1964:327-328).

These definitions provide the background for examining the role of scientific explanation. In doing so, it will be useful to distinguish between the "product" or end result of the explanation, and the "process" of creating the explanation. Some philosophers of science have used the terms "context of discovery" and "context of justification" instead of process and product (see, for example, Achinstein, 1971:165). Morgan (1973) has suggested three ways in which scientists use explanation. One of these, explanation's role in the confirmation or evaluation of hypotheses, is directly relevant to the product aspect of explanation. But the other two are more closely related to the process. These roles are those of showing the scientist where there is a gap in the knowledge of a given area and of guiding the search for the solution to a problem by helping to cut down on the nge of h

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range of hypotheses which must be considered. These two process-related roles, in particular, are significant elements to be considered in the choice of a fruitful explanatory model.

Reconstructed Logic and Logic-in-Use. In examining more fully the issues associated with choosing a viable explanatory model, it will also be helpful to employ several other concepts utilized in the philosophy of science. Two of the more useful concepts in this regard have been defined by Kaplan (1964). In his consideration of the conduct of inquiry, Kaplan contrasts what could be called the informal logic, "the cognitive style," or the way scientists actually "do" science, with the idealized, formal logical accounts of philosophers in their attempts to describe what they think scientists do. The first concept is called the logic-in-use, while the second is referred to as the reconstructed logic.

Reconstructed logics have a valuable role to play in the conduct of science. They help the scientist become more self-conscious about what he or she is doing, and thereby more aware of potential sources of error. As an element in what Kaplan defines as methodology[6], reconstructed logics aid in the process of describing and analyzing the methods used in science:

> throwing light on their limitations and resources, clarifying their presuppositions and consequences, relating their potentialities to the twilight zone at the frontiers of knowledge (Kaplan, 1964:23).

Reconstructed logics may serve as guidelines for disciplines such as archaeology which are newly venturing into pursuits couched in a scientific framework. They may also serve as a check on the logical soundness of work already completed. The reconstructed logic which is probably best known to archaeologists is the classic Deductive Nomological (DN) model as reconstructed by Hemple and Oppenheim (1948).

However, reconstructed logics are also the source of certain problems. Two of their intrinsic characteristics, in particular, are responsible. First, not all of the activities involved in science are covered by the reconstructed logic. For example, in the DN model, the purpose underlying the research and the formulation of hypotheses are both treated as extralogical matters, with the result that from the perspective of this model, much of the important activity of science is conducted 'behind the scenes' (Kaplan, 1964:10). As one can observe in archaeology, the elegance, precision, and power of the DN reconstruction have made it irresistible to some researchers, even though it does not prove to be the most useful tool either for understanding current logics-in-use or for developing new and more effective ones.

The second source of difficulties is that a reconstructed logic is not just a description, but also an idealization of scientific procedure. As such, it has a more perfected and refined form than the logic-in-use it is meant to depict. This feature can cause trouble if a logic-in-use is not distinguished from its reconstructed logic. Such confusion may result in forcing a particular logic-in-use into closer conformity with its reconstruction without necessarily improving it. As Kaplan puts it:

> It is often said that behavioral science should stop trying to imitate physics. I believe that this recommendation is a mistake: the presumption is certainly in favor of those operations of the understanding which have already shown themselves to be preeminently successful ... What _is_ important, I believe, is that behavioral science should stop

> trying to imitate only what a particular reconstruction claims physics to be. (Kaplan, 1964:11)

Those archaeologists who advocate the exclusive use of the DN approach in archaeology stand in danger of falling into this trap. As will be shown below, it is not presently possible to implement the DN approach in archaeology.[7]

The Deductive Model and the Pattern Model. In addition to the concepts of reconstructed logic and logic-in-use, Kaplan (1964:328-346) has defined another pair of concepts which are useful in this discussion of the importance of an explanatory model: the deductive model of explanation and the pattern model of explanation. Under the deductive model, explanation is based on "a logical system of deductive inference in which a particular statement is derived, by a rule of inference, from a major and minor premise, the first containing a universal statement and the second a particular statement (Wartofsky, 1968:266)." Under the pattern model "something is explained when it is so related to a set of other elements that together they constitute a unified system. We understand something by identifying it as a specific part in an organic whole (Kaplan, 1964:333)." The pattern model does not, however, exclude deduction as a process. Deduction can take place in either model (Kaplan, 1964:341-343).

The most familiar example of a reconstructed logic which fits the deductive model is the deductive-nomological (DN) model which was mentioned in the earlier discussion. The DN model of explanation is distinguished by the use of a "covering law" as the universal major premise in its explanatory accounts. The explanatory argument is said

to explain the phenomenon or event under consideration by subsuming it under a covering law (Hempel, 1966:51). Thus, for the DN model to operate, it must be possible to deduce the occurrence of the phenomenon or event to be explained from the covering law (Meehan, 1968:9). The power of a deductive explanation is dependent upon the strength of the deductive reasoning which links the phenomenon or event to the law. When a phenomenon or event is deductively subsumed under a covering law, the truth of the event is established through transfer from the general law which by definition must be a true and universal statement (Meehan, 1968:9; Nagel, 1961:21-22; Rice, 1975:9).

Another less-familiar reconstructed logic, the Meehan System Paradigm (Meehan, 1968), fits the pattern model of explanation. Instead of a covering law approach, Meehan's explanatory model is based on establishing isomorphism between a formal pattern (the system) of variables and rules linking those variables, and a description of the phenomena to be explained couched in terms of an appropriate conceptual framework. The stated purpose of the explanation allows the adequacy of the explanation to be judged.

Earlier, in considering the concept paradigm, the key role of the explanatory model was noted. The basic concepts just discussed in this section -- paradigm, explanation, logic-in-use vs. reconstructed logic, and deductive model vs. pattern model, -- should aid in the following evaluation of alternative explanatory models, and hence in the choice of an explanatory model appropriate for this study.

EVALUATION AND CHOICE OF EXPLANATORY MODEL

Most discussions of explanation in the recent archaeological literature have centered on the deductive model (Binford, 1968; Fritz and Plog, 1971; Hill, 1972; Watson _et al._, 1971), and in particular on the DN model of explanation. However, it is clear that what Flannery (1973) has called the "law and order" segment of the archaeological community have been so impressed by the elegance and power of the reconstructed logic embodied in the DN model, that they have failed to consider its weaknesses and to look at the available alternatives (Morgan, 1973). Indeed, the failure even to consider carefully the nature of explanation in the behavioral sciences may be attributed to this fascination with the DN model (Tuggle, 1972).

Problems with the DN Model. However, explanation in general, and the DN model in particular, for some time have been the subject of debate among philosophers of science as well as among scholars in other disciplines (Adams, 1973; Chaney, 1972; Tuggle _et al._, 1972). It has become increasingly clear from this debate that the DN model embodies a number of unresolved problems which constitute major obstacles to the model's effective use by archaeologists, given the present state of the discipline. Some of these obstacles will be discussed briefly below, but the interested reader is referred to the following references for further discussion of these issues (Chartkoff, 1972; Kaplan, 1964:343-346; Meehan, 1968:7-30; Monge, 1973; Morgan, 1973; Rice, 1975:9-11; Tuggle _et al._, 1972; Wartofsky, 1968:267-272).

The first major problem in the use of the DN model stems from its rigorous requirements for a valid covering law (Stickel and Chartkoff,

1973). While there is some controversy over covering law requirements, one list of essential properties is given by Chartkoff:

> Explanatory laws possess exacting properties including those of (1) spatial and temporal universality; (2) variables of spatial and temporal continuity; (3) necessary and sufficient conditions; (4) asymmetrical cause-and-effect relationships; (5) demonstrated validity; and (6) a set of considerations which define and justify the articulation of the described variables, including (a) syntactical considerations regarding the structure of law-like statements; (b) the logical relationship between these statements and others in a coherent system of explanation; (c) the functions which in a scientific inquiry are assigned to law-like statements; and (d) the goodness of fit between a proposed law and the existing state of knowledge. (Chartkoff, 1972:5)

From this list, it is clear that archaeology has no explanatory laws and that acquiring them will take some time. Some archaeologists have suggested and attempted to use law-like generalizations as a substitute for laws. This procedure has serious logical problems, however, because if the major proposition of the deductive statement is not demonstrably true, its truth cannot be transferred to the event or phenomenon to be explained.

There are basically two procedures established by the DN model for determining the truth of a universal statement or potential law: logical determination by subsuming the statement under an even more general law and positive verification through empirical testing. Both of these procedures embody some serious logical difficulties. Logical determination by subsuming a law under a more general law does not solve the induction problem either; it just pushes it further up the hierarchy of explanatory propositions. If there are no laws to begin with, there are no "more general laws" under which a potential covering law may be subsumed.

Empirical verification is vulnerable to what several scholars have called the "induction problem" (Monge, 1973:8; Meehan, 1968:9-12). At the root of the induction problem is a basic contradiction. The logical truth of a proposition cannot be established through empirical testing because it is impossible to find and test every possible empirical situation (Rice, 1975:10). Empirical verification of a covering law also involves a further related problem. A potential law must have empirical referents, yet empirical referents, by their very nature, are not timeless and universal, two of the most basic requirements for a valid covering law. The attempt to fulfill a logical requirement with an empirical statement results in a confusion of the empirical and logical realms and consequently a tendency to overlook the significance of the distinction between logical competence and the possession of relevant empirical knowledge. Both logical and empirical information are required for adequate explanation, and failure to separate them adequately can lead to one or the other being ignored. Philosophers have considered a number of solutions to the problem of empirical verification. Some (Nagel, 1961:43) have suggested that after continued testing, laws are accepted as cognitively true, if not logically true (Rice, 1975:10).

Watson _et al_. (1971) have suggested that the solution to these problems lies in mutual agreement among archaeologists as to the degree of testing necessary to constitute adequate empirical verification of a law, and a "common understanding" concerning which "lawlike generalizations" should be accepted without testing as basic assumptions, and which should be tested (Watson _et al_., 1971:46,47; Rice, 1975:10). However, popular opinion is not a valid means of affirming logical truth in any case. All of the solutions proposed are untenable and the logical problems of the DN model remain unsolved.

A second major problem of the DN model is that it is based on a single form of logic, namely set inclusive logic. Although there is nothing inherently wrong with this form of logic, there are others which are available. In dealing with new and highly complex phenomena which are governed by an unfamiliar cultural system, being able to draw on other sets of logical rules in constructing explanations may have a distinct advantage in terms of payoff (Monge, 1973).

Tuggle et al. (1972) have also argued that the inherent logic of the DN model has another disadvantage. They point out that the DN model can easily lead to thinking in terms of oversimplified monocausal or chain-causal explanations. Clearly, such simplistic explanations often are not in keeping with the complexities of the problems under consideration or with the data being observed in archaeology. Dekin has shown why multiple causes must be considered in arctic research, and similar arguments have been made for archaeology as a whole (Cole and Kleindeinst, 1974).

A third major problem arises because the DN model lacks the means to evaluate the appropriateness of a particular explanation. All DN explanations are assumed to be of uniform quality. That is, the purpose of the explanation is not an element in the reconstruction of DN logic, and hence the model provides no criteria for determining when an event and a covering law are sufficiently linked for explanation to occur. Accordingly, the DN model fails to deal with the problem of evaluating the relative merit of two different explanations of the same event (Rice, 1975:10).

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One other partial explanatory model should be discussed in connection with the deductive model, namely, the hypothetico-deductive (HD) approach. According to this method, the scientist begins with a problem, in the light of which a hypothesis -- which may be a law -- is formulated. Consequences (frequently called test implications in the archaeological literature) are derived deductively from the hypothesis, possibly in conjunction with other assumptions, and are subjected to empirical tests (Achinstein, 1971:110; Medawar, 1969). The major difference between the DN model and the HD model seems to be that the DN model requires a law to operate, whereas a law is not essential to the HD approach. Although the HD approach is not identical with the DN model, it is often viewed as very similar or at least closely allied because the philosophers most closely associated with this view, such as Popper and Hempel, have tied it closely to the testing of laws. Thus, for example, one finds Hill (1972), as an advocate of the HD approach, echoing many of the basic concepts involved in the DN model. Similarly, Tuggle et al. (1972) have pointed out that Fritz and Plog (1971) seem to be confusing the DN model with the HD approach, perhaps because they unconsciously realize the difficulty involved in obtaining major propositions of the caliber of a law.[8] However, if the HD approach is severed from its implied connection with laws and viewed primarily as the formulating and testing of hypotheses, the HD approach can be used as an element in many different kinds of explanatory models. Indeed, it is one of the basic tenets of the general scientific paradigm outlined earlier.

<u>An Alternative Pattern Model: The Meehan System Paradigm</u>. At the present time, these three major problems with the DN model constitute significant obstacles to its use for productive research in archaeology. Consequently, an alternative explanatory model has been sought. The pattern model of explanation is an attractive possibility because it does not require the universal generalizations or covering laws necessary in the deductive model. The most useful and explicit reconstructed logic consistent with the pattern model is Meehan's System Paradigm (1968). One reason Meehan's model of explanation provides a valuable alternative to the DN model may be that Meehan is not a philosopher, but a social scientist, specifically a political scientist who has been involved in actually doing social science research, as well as in modeling the methodology it uses. By contrast, Hempel and Oppenheim, who did the original reconstruction of the DN model, are philosophers of science who were describing what they thought scientists, and especially workers in the physical sciences, did. In addition to his position within science, instead of outside looking in, Meehan's model has benefited from his experience with research in a discipline which like archaeology, lacks a large body of highly structured and integrated theory that is accepted by the discipline as a whole.

Consistent with the pattern model of explanation, Meehan defines explanation as:

> a way of organizing human experience to show how or why events occur by linking those events to other events according to stipulated rules (Meehan, 1968: 24).

According to Meehan's model, the success of an explanation is judged n pragma

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on pragmatic rather than logical grounds. An adequate explanation must meet two requirements, both of which are evaluated in terms of the explicitly stated, specifically defined purpose of the research. In order to be considered satisfactory, an explanation must be able to 1) predict future events and 2) provide some means of controlling those events, at least in principle.

According to Meehan, the mechanics of scientific explanation involve the "application (or relating) of a logical system to a description (Meehan, 1968:31)." Such an explanation is thus organized into two basic parts: the logical and the descriptive or empirical. The logical part of an explanation, which Meehan (1968:48-53) calls a system, is a formal logical calculus consisting of a set of variables and a statement of the conditions under which the relationships among the variables depicted in the calculus can be expected to hold. This statement also functions as a statement of the boundaries of the system. Since a system is bounded, and all its internal relationships are logical, a change in the value of one set of variables will bring about a predictable change in the values of other variables in the system. Such changes are termed the "entailments" of the system (Rice, 1975:6).

The empirical part of an explanation is called simply a description, and is the record of an historical event (and is always stated in the past tense). A description depicts a set of entities and one or more propositions relating those entities. Archaeologists are primarily concerned with that type of description which records change -- a dynamic description. In a dynamic description, the relational propositions link a change in the state of one or more of the entities the tha

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to a change in the state of one or more other entities in the description (Meehan, 1968:39-42; Rice, 1975:7).

To relate a logical system to an empirical description involves two processes termed loading and fitting. Loading a system involves giving meaning to the logical variables by associating each variable with a concept (Rice, 1975:8). The concepts and relationships necessary for loading the system are supplied by the parts of the paradigm called the controlling and operational models. Fitting a system involves linking each concept of the loaded calculus to the empirical world using "a set of rules of correspondence that specify the perceptions that identify the concept (Meehan, 1968:62; Rice, 1975:7)." A good fit requires that each of the loaded concepts or variables be identified with one of the entities in the description. The rules regarding changes in the logical system variables must also parallel the relational propositions of the description (Meehan, 1968: 89). Once this fit is obtained, the entailments generated by the formal logical calculus may be transferred from the logical system to the empirical situation. By knowing all the entailments of the system, it is possible in a good explanation to predict the changes which will take place in the empirical situation (Rice, 1975:8).

Since there can never be complete isomorphism between a logical system and the empirical world, one additional feature of the explanatory system is necessary: the "cp" or ceteris paribus clause. The cp clause is designed to account for the inevitable error involved in measurement, in identification of the empirical referents of the various concepts, and probably also in the choice of concepts with which the system is loaded (Meehan, 1968:104-105). The cp clause also aids in establishing the limits of permissible error. If this part of the loaded system must be consistently fitted to large values in the description, the explanation has serious problems. Such problems call for the revision of the existing logical system or the construction of a new one (Rice, 1975:8).

Whether or not a given explanation is accepted as satisfactory or rejected as inadequate depends entirely on how well it fulfills the purpose of the explanation with regard to prediction and control. In some situations, a weak explanation may be quite adequate for the purpose at hand, but in others it may be totally unsatisfactory. The strength of the explanation is also highly dependent upon the amount of variability incorporated in the _cp_ clause (Rice, 1975:8-9). The presence of the _cp_ clause and the explicit ties to purpose in Meehan's model allow a researcher to begin with a problem about which little is known, to construct a relatively weak explanation at first and then to gradually strengthen the loading concepts and the calculus as more becomes known.

Although Meehan's model of explanation has been mentioned in various archaeological publications (Chartkoff, 1972; Dunnell, 1971a; Tuggle _et al._, 1972) an example of its use in solving an archaeological problem has not been available until very recently. The reason may be due in part to one of the few difficulties in Meehan's presentation, namely his failure to elaborate on how the process of identification, which is involved in fitting the loaded calculus to the empirical situation, is actually completed. In providing one of the first examples of how Meehan's model may be used to solve an archaeological problem, Rice (1975), drawing on Dunnell (1971a), has shown how this step should be handled:

> In a scientific discipline, where all steps must be open to evaluation, specific identifications are stated as hypotheses. Such a hypothesis postulates a correspondence between an ideational concept, or class, and a particular physical event, and is tested by finding attributes of the event which are analogous to each of the definitive features of the concept. (Rice, 1975:7-8)

From this brief description of the Meehan system paradigm, its advantages as a model for explanation should be relatively clear.[9] First, it does not require laws or other propositions of a universal nature, as does the DN model. This feature does not preclude its use as a means of testing highly general propositions, nor does it mean that the rules used to establish the relationship between variables in the logical calculus may not be considered universal statements (Rice, 1975:12).[10]

Second, Meehan has achieved a solution of the 'induction problem' of the DN model by making the separation between the logical and empirical explicit. The system is evaluated on logical grounds; the fit between the loaded system and the description is evaluated on empirical grounds. One is never in the position, as with the DN model, of trying to evaluate a logical entity by empirical means.

Third, Meehan's System Paradigm possesses an intrinsic evaluation process, an advantage which is not present in the DN approach. The stated purpose of the explanation is integral to the model itself; it is not an extralogical matter. Hence, the adequacy of an explanation for prediction and control can be judged. Fourth, and closely related, because the purpose of the explanation is integral to the logic, the model can be self-correcting, an essential feature of the scientific method (Chaney, 1972:992; Kerlinger, 1964:7-8; Monge, 1973). Unlike the DN model, explanations are not all considered of uniform quality, and hence the possibility exists for beginning with a weak model and strengthening it through subsequent successive approximations. Such a feature allows a flexible interplay between data and hypotheses which is highly desirable (Tuggle et al., 1972).

Fifth, unlike the user of the DN model, the user of the Meehan model is not limited to one kind of logic. The logical system may be constructed on the basis of any number of valid formal logics so that the researcher is free to use that logical system which displays the best isomorphism with the empirical observations under study. Such flexibility can be particularly valuable for a researcher working with data from cultural systems other than his or her own (Monge, 1973).

Sixth, the Meehan model allows a greater flexibility than the DN model. Its system can be constructed with varying degrees of complexity to accommodate the complexity of the phenomena at hand (Monge, 1973) and of the problem under consideration. This feature is particularly valuable because the explanation of cultural phenomena can be enormously complicated (Leach, 1973). Chartkoff (1972) has suggested that the Meehan model may provide a useful framework for employing the complex canonical model which Clarke has proposed (Clarke, 1968:45). In addition, the Meehan model does not promote a monocausal or chain causal point of view, as does the DN model (Tuggle et al., 1972). It can easily accommodate a multivariate operational model and multiple working hypotheses.

Finally, the Meehan model provides the user with a more accurate grasp of the limitations of explanation. The deductive model of

explanation presents an image of completion, a total, unconditional process accomplished with surety and finality. However, in considering some of the limiting aspects of explanations, Kaplan (1964:351-355) indicates that in one way or another, they are partial, conditional, approximate, indeterminate, inconclusive, uncertain, intermediate, and limited in their scope. The Meehan model with its explicit use of the cp clause and purpose-relative goals, is much more in keeping with this broader view of the limitations of explanation.

The specific advantages that the Meehan model presents for a discipline such as archaeology, which is relatively new to a scientific approach, should be clear. Because laws, in the sense of the DN model, are not a prerequisite, explanation of both idiographic and nomothetic problems can proceed immediately. With the clear separation of logical and empirical operations, evaluation of each realm can take place without confusion of the two realms and of their respective roles. Since all explanations are not regarded as of a single high quality, explanations of virtually unknown situations can be commenced with relatively weak systems, and then strengthened as more is learned. These explanations can also be evaluated at any point in their development since purpose is clearly incorporated in the model. The flexibility of the model with regard to the logic employed, the degree of complexity available, and the ease with which multiple variables are incorporated, are additional qualities especially attractive for a discipline which is barely into adolescence. Arctic research is a subfield of archaeology which has only just set off down the road that other subfields of the discipline have already traveled; it too, should find these advantages of particular value in facilitating productive research.

A few closing comments regarding this particular study are in order. It should be clear that further description of the space-time framework of the eastern arctic is not among the goals of this study. Instead, this work focuses on beginning to understand how Dorset adaptation to the physical environment operated. In general, the study asks: Within a framework of rather rigid environmental constraints, how did the Dorset population cope with environmental variability? More specifically, and within the limitations of the data from the Nanook Site, the immediate goals of this research are to attempt to explain 1) Why there is cultural continuity in the occupation of the Nanook Site over a 500-600 year period, and 2) Why the Nanook Site location was ultimately abandoned. It should be apparent from the discussion above that the limitations of the "traditional paradigm" generally employed in arctic research make it inappropriate for solving these problems. Instead, Dekin's general scientific approach seems to offer a greater possibility for achieving a successful solution. Yet, as was noted above, Dekin's approach is very general and a more specific strategy needs to be defined. That strategy should include an explanatory model, one or more controlling models, and one or more operational models. While all three types of models play key roles, the explanatory model with its inherent advantages and limitations is most important. It is clear that those aspects of the Meehan model which make it highly useful for solving many current arctic problems also make it a good choice for solving the problems basic to this research.

The specific details of implementing this explanatory model, including not only the variables and the rules which constitute the system, but also the loading and fitting of the logical calculus, will be discussed in II of Chapter 4. Fitting will be accomplished according to a pattern established by Rice (1975; Chapter 5) which uses three sets of hypotheses: hypotheses treating the identification of the system variables, hypotheses to demonstrate isomorphism, and hypotheses treating the operation of the rule. Before these steps can be taken, however, it is necessary to examine the controlling and operational models (Chapter 3) which have guided this study, and to present the empirical desoription couched in terms of the concepts provided by these models (I of Chapter 4).

NOTES

1. As Rice (1975:15) points out, the current need for such explicit discussion of many aspects of archaeological research is a clear indicator of the youthfulness and state of change within the discipline. Kuhn (1970a) has also pointed out that the need for the explicit discussion of methodological and theoretical issues is characteristic of periods of paradigmatic change.

2. In her critical essay, "The Nature of a Paradigm," Margaret Masterman (1970) has examined the multiple meanings which Kuhn has given to the word "paradigm." Masterman finds no less than twenty-one different senses in which Kuhn uses the term. She condenses these twenty-one uses into three main groups: the philosophical or metaphysical usage, the sociological usage, and the more concrete, artifact or construct usage. However, for the purpose of this discussion, Kuhn's own breakdown of the concept of "paradigm" given in the "Postscript" to the 1970 edition of <u>The Structure of Scientific Revolutions</u> proves more useful.

3. The use of the terms "model" and "paradigm" in the current archaeological literature is often not very clear. In the interest of further clarifying the distinction which is made at this point in the discussion, the reader is urged to peruse the definitions of <u>model</u> discussed and quoted on page 52.

4. The problems with allowing Kuhn's model to influence our thinking too strongly are very similar to the problems inherent in placing too great an emphasis on a single reconstructed logic noted on page 32.

NOTES (con'd.)

5. Pointing out the limitations of a purely inductive explanatory model does not indicate that induction *per se* is wrong or unnecessary. On the contrary, as several authors have stated (for example, Chartkoff, 1972; Medawar, 1969; Thompson, 1972) a reciprocating balance between induction and deduction is necessary for the successful operation of an explanatory model involving hypothesis testing. Chartkoff, in particular, makes this point in support of the idea that archaeologists should choose their paradigm for its productivity for research rather than on some programmatic grounds. The strategy Chartkoff uses in his paper, namely downplaying the difference between the traditional "empiricist" approach and the newer "positivist" approach, is very much in keeping with the spirit of reconciliation in the early '70s on the part of some "new archaeology" advocates following the sharp, and sometimes vituperative debates of the late '60s (Longacre, 1973:332).

In Chartkoff's view, the differences between the historical and processual approaches "lie not in the Empiricist-Positivist dichotomy, but in the recognition of significant variables and their articulations, and in increased emphasis on tests of postulates (1972:4)." Newer controlling and operational models are becoming more widely accepted by traditionally-oriented archaeologists so that the issue of recognizing different significant variables and variable relationships becomes less important. Yet the question of testing remains crucial; it should not be played down. For without hypothesis testing, no approach can weigh alternatives in a manner exposed to general discussion and review. The absence of testing is a hindrance to fruitful research.

6. Methodology has been defined by Kaplan as, "the study -- the description, the explanation, and the justification -- of methods, and not the methods themselves (1964:18)." Chartkoff (1972) has used a more general definition based on both Kaplan (1964) and Nagel (1961), "Methodology in science may be regarded as the strategy for raising and solving research problems (2)."

7. Examples may be found in Watson *et al.*'s (1971:34ff) discussion of Longacre (1963, 1966, 1968) or Watson's (1973a) distortion of Meehan's system paradigm. Both of these cases probably involve another problem, namely the confusion of the DN model with the hypothetico-deductive method, a problem discussed further on in this chapter. For comment on the problem of forcing a Hempilian reconstruction on another logic-in-use, see also Sabloff *et al.* (1974).

8. Tuggle *et al.* have argued that the hypothetico-deductive method is "the primary method employed in most archaeological research, not the 'traditional research design' (1972:5)." They may be correct if their definition of the HD method is accepted.

> It is unnecessary to have laws as such to use this method or to be testing for laws. In its simplest form it only requires that a hypothesis or proposition have deductively derivable

NOTES (con'd.)

> consequences which _may_ be tested against empirical data. (Emphasis added, Tuggle _et al._, 1972:5)

However, if Achinstein's (1971) definition of the HD approach is examined (see page 39 of this chapter), there is a significant subtle difference. In Achinstein's definition the testing of hypotheses is not left as a possibility by the word "may," but made a certainty by the word "are." Certainly the bulk of archaeological studies produce propositions which are testable, but as yet, very few of these studies contain tests of these propositions. Since hypothesis testing, as an element in a scientific approach which allows self criticism and correction, is an important issue, Tuggle _et al._'s definition of the HD method and application of that definition to the "traditional research design" is misleading and counterproductive.

9. To avoid repeating the error which Watson _et al._ (1971) made in failing to examine a diversity of non-archaeological discussions of the DN model (Morgan, 1973), an effort was made to find book reviews or other sources of comment on Meehan's (1968) model. This effort showed that with one exception, the other social and behavioral sciences have generally ignored it. After some searching, two book reviews and one article were located. Both book reviews give Meehan unfavorable comment. In the first review, Bell (1969) makes the same mistake as Watson (1973a), and confuses Meehan's model with the deductive model of explanation. In the second review, Rodgers (1969) mostly paraphrases Meehan's major points and concludes with a paragraph which mainly illustrates how little interest (or knowledge) he has in philosophy of science. Neither review contains much insightful criticism or adds to the understanding of Meehan's model.

In the article, however, Monge (1973) finds Meehan's model very useful, and some of his comments have proven valuable in writing this chapter. There are some interesting parallels between archaeology and human communication as disciplines which, in part, account for the usefulness of Monge's paper. Both are young fields, at least as sciences. Both deal with human behavior in contexts where cultural differences can be significant. Both are exploring the value of General Systems Theory for creating operational models, although communication has done so with a great deal more depth and sophistication than archaeology. However, it is also interesting to note that the field of human communication has articulated a far more extensive and well-developed body of theory than archaeology.

10. The rules of a logical calculus are judged on the basis of logical consistency and may be employed as laws in a deductive model of explanation. Because such rules relate only formal units and are subject only to logical evaluation, they avoid the difficulty encountered under the DN model when a logical construct must be evaluated by empirical means. For further discussion of this issue as well as some excellent critical comment on the problems with Tuggle _et al._'s (1972) treatment of this problem, see Rice (1975:14).

CHAPTER 3

CONTROLLING AND OPERATIONAL MODELS

INTRODUCTION

After considering the explanatory model employed in this research, it is necessary to call attention to the two other parts of the paradigm: the controlling and operational models. Thus, the discussion in this chapter begins by briefly reviewing the definition of model presented in Chapter 2, along with a short discussion of the issue of the relationship between models and theory. Once this groundwork is established, the controlling models are delineated, and the operational models are presented.

The purpose of this chapter is not to present a new theoretical distillation, but rather to provide an explicit account of the theoretical structures which have shaped the course of this research. Because the pattern model requires not only that the problem be specified clearly, but also that it include some change which must be explained, the problem for this research has been stated in terms of two questions: why was the Nanook Site occupied periodically for 500-600 years without change, and why was it finally abandoned? The next step is to provide the two basic elements of the explanation under the pattern model, the description and the system (see Chapter 4). However, in order to complete this next step it is necessary to provide the concepts which serve as the framework for these two parts of the explanation. These concepts, which are ultimately expressed as variables and relationships between them, are derived from the controlling and operational models discussed in this chapter.

Chapter 2 defined and contrasted the concepts of paradigm and model. Since researchers sometimes use these terms interchangeably, it is useful to review the specific definitions employed in this study. Paradigm is defined as "the entire constellation of beliefs, values, techniques, and so on shared by the members of a given scientific community (Kuhn, 1970:175)"; paradigm may also mean a specific exemplary or prototypic solution to a problem in science. Model, in contrast, although used to depict an exemplary solution, does not depict a specific solution; it denotes an abstraction of the essential steps or dimensions of the exemplary solution. An additional definition of model which facilitates an understanding of its use is:

> ... a simple, largely accurate, predictive framework for structuring and investigating archaeological data. ...Essentially, models are hypotheses or sets of hypotheses which simplify complex observations whilst offering a largely accurate predictive framework structuring these observations -- usefully separating 'noise' from information. (Clarke, 1968:32)

As noted in Chapter 2, three kinds of models can be used to delineate the structure of a particular paradigm: an explanatory model, one or more controlling models, and one or more operational models.

A major reason for reiterating these definitions is the possibility of confusion in the following discussion. The concepts of controlling model and operational model are drawn from Clarke (1972), but Clarke refers to different controlling models as "paradigms".

Since this usage is not in keeping with the definitions set out for this study, the reader should note that "paradigm" enclosed in quotation marks refers to Clarke's special usage of the term. Also closely entwined and easily confused, and probably for good reason, are the concepts of model and theory. A definition of theory helps explain why.

In R. C. Dunnell's (1971a:200) succinct definition, theory is a system of units and relationships between units that provide the basis for the explanation of phenomena.[1] As Kaplan (1964:299) further notes, theory puts things into a system, and in doing so makes sense out of what would otherwise be "inscrutable or unmeaning empirical findings." In performing this task, theory functions throughout inquiry; it does not just provide input at the point of successful conclusion. From this model of theory, it is easy to see why the terms theory and model are often confused. In fact, interchangeable usage may be justified on the grounds that some theories are indeed models and that both make abstractions.

But many investigators, including Kaplan, regard models as structural analogies; and even though they may have many characteristics in common, not all theories have analog structures. Conversely, many researchers, including Clarke, feel "The existence of a model presupposes the existence of an underlying theory, since a model is but one simplified, formalized and skeletal expression of a theory . . . (1972:3,4)." Thus, while not all theories can be depicted as models, all models would seem to have some underlying theory, even though, in some cases, that theory may be at a very low level of abstraction.

CONTROLLING MODELS

Controlling models are generally more closely enmeshed with theory than operational models, for they embody the archaeologist's philosophy, the approaches the archaeologist chooses to use, the methods which, for that investigator, prove most workable, and the constraints which these choices impose (Clarke, 1972:5). An individual's choice of controlling models depends on a number of factors, such as experience, personality, educational background, and contemporary trends in the discipline, and not all of these factors are directly related to the rational processes generally thought to govern such choices.

Clarke views the controlling model as a plastic bag which encompasses the archaeologist and the chosen operational models. Although feedback occurs among all the elements involved, in effect, the archaeologist operates from within the bag by pushing selected pieces of operational models against archaeological reality, constantly seeking goodness of fit. Nevertheless, the constraints of the controlling models obscure a full perception of the reality (Clarke, 1972:5). Clarke's ironic image illustrates some of the positive and negative qualities of controlling models (or any model for that matter). Since the function of these models is to show which variables and relationships are selected for attention, some variables and relationships invariably will be omitted, preventing the researcher from seeing the total picture.

Another notable aspect of controlling models is the interaction between these models and the problems which the researcher chooses to examine. If a particular controlling model is deeply ingrained, the problem may be chosen because it is solvable with a particular controlling model, rather than the controlling model being chosen because it can help solve the problem!

The "traditional" paradigm in archaeology had only one controlling model: culture history. However, as was already noted in Chapter 2, a number of weaknesses make this model inappropriate and inefficient for the solution of the problem posed for this research. However, it is not necessary to choose just one controlling model. As Clarke (1972:7) notes, "we suddenly have a number of new, competing paradigms, ... they are international, and ... some individual archaeologists simultaneously embrace several of them". Instead, the controlling models which have influenced this investigator's choice of operational models are two of the newer "paradigms" which Clarke notes, with methods drawn from a third.

<u>The Ecological "paradigm"</u> The first of these controlling models is what Clarke calls the Ecological "paradigm". The Ecological "paradigm" involves:

> the detailed study of archaeological sites as an integral part of the mutually adjusting environmental and ecological systems in which they were once adaptively networked. Linked to ethology, economics, and demography, and more deeply involved with faunal and floral contextual evidence, rather than with the artifacts (Coe and Flannery, 1964, 1967; Higgs, 1972; Higham, 1968a, MacNeish, 1961, 1962). (Clarke, 1972:7)

Operational models drawn from the Ecological "paradigm" are particularly appropriate for this research for several reasons. First, the arctic can be characterized as an ecosystem with <u>physically controlled communities</u> (Saunders, 1969); that is, the populations which inhabit the area, including Homo sapiens, are more strongly influenced by the exigencies of the physical environment than they are in almost any other geographic region. Second, the cultural system under consideration is the only system in the area during the time under study; therefore, competition with or influence from other cultural systems is not a factor for consideration. Third, the large quantity of faunal data from the Nanook Site and the nearby Morrison Site can be analyzed and used very effectively under this controlling model. Since relatively little is known about paleoenvironmental factors related to Dorset archaeology, and only two previously reported Dorset sites, the T-1 Site and the Tyara Site, have more than a cursory account of faunal remains reported for them, and in both cases the analysis of these remains was not extensive (Collins, 1956, 1957; Taylor, 1968)[2], this information should make a valuable contribution to the knowledge of the archaeology of the period.

The Geographical "paradigm." However, the faunal data, along with the information gathered on climatic change and animal resource response to that change, are only part of the data for this research. There are almost 5,000 artifacts which also deserve attention. The controlling model which has governed much of the analysis of this material is what Clarke calls the Geographical "paradigm". The Geographical "paradigm" involves:

> the study of sites as patterned systems of features and structures within systems of sites territorially distributed over landscapes in a mutually adjusted way. At the micro-level linked to architectural theory and settlement archaeology, at the macro-level with locational theory and spatial relationships; principally focused on sites and the spatial manifestations of activity patterns (Chang, 1968;

> Trigger, 1966; Ucko, Dimbleby and Tringham, 1971; March and Echnique, 1971). (Clarke, 1972:7)

While not as much has been drawn from the Geographical "paradigm" as from the Ecological "paradigm", it too has important advantages for this research. Viewed in close conjunction with many of the ideas supplied by the Ecological "paradigm", the Geographical "paradigm" is appropriate for three reasons. First, it helps to point out that there is significance to the spatial distribution of resources in the Dorset Eskimo environment. Second, this "paradigm" suggests that when the distribution of these resources changes, as indicated by various aspects of the operational models generated from the Ecological "paradigm," the physical locations used by people dependent on these resources will also have to change. Third, operational models generated by the Geographical "paradigm" provide the archaeological variables for demonstrating such change in both faunal and artifactual data.

The Morphological "paradigm." Methods drawn from a third "paradigm", the Morphological "paradigm" are also employed in this study in order to test hypotheses based primarily on operational models drawn from the other two controlling models. The Morphological "paradigm" involves:

> the detailed study of artefact and assemblage systems, especially in terms of the widely general regularities involving their intrinsic structures and relationships, mainly using computer techniques. Intimately involved with the numerical, statistical and taxonomic approaches (Clarke, 1968; Gardin, 1970; Hodson, 1970; Kolchina and Shera, 1970). (Clarke, 1972:6-7)

Use of the Morphological "paradigm" is generally associated with approaches to data which are almost exclusively inductive, and therefore the ways in which many of the models and methods associated with this controlling model are used are not appropriate for this study. However, some of the statistical techniques, namely Cluster Analysis, Multi-dimensional Scaling, and Multiple Discriminant Analysis, which are closely associated with the Morphological "paradigm," have proven extremely valuable in grouping data for hypothesis testing in this research.

OPERATIONAL MODELS

As preliminary discussion in Chapter 1 noted, current research in arctic archaeology points to climatic change as one of the factors which may be responsible for many changes seen in arctic archaeology, including, perhaps, the change (abandonment) observed at the Nanook Site. The effects of climatic change on a human population can be understood in terms of four orders of interaction (Table 1) Barry et al., n.d.). The first order interactions are factors relating to pure physical survival. Second order interactions are related to limitations on the availability of resources. Travel limitations which affect ability to hunt, transmit disease, etc., form third order interactions. Fourth order interactions are related to the effect of travel or resource limitations on susceptibility to disease, technological innovation, and so forth.

First order interactions are not likely to affect the southern Baffin Island area to a great extent since, by arctic standards, temperatures in this area remain well within human tolerance, given prehistoric Eskimo technology. Third and fourth order effects also receive less attention since they might be difficult to detect within

Table 1. The effects of climatic change on arctic populations. (Based on Barry *et al*., n.d.)

Order of Interaction	Climatic Factors	Cultural Significance
1st	Minimum temperature, wind speed, heat losses from the body	Physiological limitations on survival
2nd	Temperature, wind speed, snow cover, net radiation	Limitations on the availability of resources (food, fuel, building and clothing materials)
3rd	Temperature, wind speed, snow cover	Travel limitations; susceptibility to disease, and so forth
4th	Temperature, wind speed, snow cover	Effect of travel or resource limitations and susceptibility to disease, on technological innovation, maintenance of family and social ties, and so forth

the relatively small area encompassed by the larger group of sites in the Cape Tanfield area used for some of the tests in this analysis. (However, third and fourth order effects have been used by Dekin (1975) for testing his Vectors of Environmental Change Model, discussed in Chapter 4 and 6). Thus, attention in this study is given primarily to second order interactions, that is, to climatic factors which bring about limitations on the availability of resources for food, fuel, building, and clothing materials. In the case of most traditional arctic cultures, harvested products from animal populations provide many of these resources.

The Ecological "paradigm" provides a very useful framework for examining second order interactions. Since an ecological approach implies an understanding of adaptation to the environment, it will be valuable to take a closer look at the environment to which the Dorset population was adapted. The following summary relies heavily on the ideas of M. J. Dunbar, (1960, 1968, 1972, 1973) arctic ecologist and oceanographer, who has supplied some of the best summaries available of the vital characteristics of arctic ecosystems.

The Arctic Ecosystem. The arctic ecosystem is rather new in an evolutionary sense; it dates back only to the end of the Pleistocene. Because it is comparatively new, it is also rather simple; typical of simple ecosystems, it has relatively few energy paths. Such simplicity means that oscillations in the characteristics of either the biotic community or the non-biotic environment have immediate and direct effects on the entire system. Thus, arctic ecosystems contrast with more mature ecosystems in which the effects of changes in energy flow are muted by the multitude of energy paths available.

Another important characteristic, which will become even more evident in the discussion of animal responses to climatic change in Chapter 4, is the major structural difference between the terrestrial and the marine portions of the arctic ecosystem (Fitzhugh, 1974). Most important to human predators is the fact that land animal populations are considerably less stable than marine populations. Caribou and muskox undergo drastic population crashes and regional shifts in response to predation, fire, snow conditions, disease, insects, and other factors. Smaller animals, such as lemming, hare, fox, and lynx which are generally less important to human populations, undergo strong predator-prey cycles. To a human predator dependent on terrestrial resources, the effects of even a single population oscillation or migration shift among these species can be disastrous.

In contrast to the terrestrial communities, the marine portion of the ecosystem is considerably more stable. Although not entirely free of population fluctuations, productivity in most arctic waters appears to be more steady. Less markedly fluctuating temperatures and a more diverse food web account in part for this greater stability. In addition to the difference between the terrestrial and marine segments of the ecosystem, there are also significant areal differences in stability and productivity. However, these differences are not of direct concern in this study.

Arctic ecosystems as a whole are subject to a number of different kinds of oscillations. Seasonal variations in such basic factors as heat, light and standing crop are drastic. Longer term fluctuations, ranging from a few years (for small mammal population cycles, for example) to centuries (for long term climatic changes), also occur and in turn have far-reaching effects on the ecosystem. Fluctuations in such basic factors directly affect the entire food chain.

In a recent discussion of the character of the arctic ecosystem, Fitzhugh (1974) has called attention to this issue. Because the arctic displays such "unstable" (MacArthur, 1955) or "unpredictable" (Slobodkin and Sanders, 1969) characteristics as physiological stress, high predation and competition, low interaction between organisms, and generally low numbers of species per given unit number of individuals, there is considerable doubt as to whether the arctic will ever evolve into a stable ecosystem. Instead, the evolution of resiliency or the ability to withstand oscillations, rather than the evolution of

stability, may be the more important concept in an understanding of the arctic ecosystem.

Two types of strategies which exist among arctic populations allow them to survive under these conditions. The first strategy, typified by many of the small land mammals in the arctic, relies on large numbers and broad geographic scale for survival. When perturbations in the ecosystem wipe out the population of that species in one area, it can be repopulated by survivors from less affected locations. A broad range of species diversity, or the ability to adapt to a variety of adaptive constraints, constitutes the second strategy for survival. The human population of the arctic, which can be viewed as a population of sophisticated predators (Wilkinson, 1972), utilizes this strategy. The alternative and substitute subsistence strategies which Balicki (1968) describes, for example, have played a major role in allowing human populations to survive in the arctic.

Since the availability of animal populations which served as human resources plays such a basic role in the explanation of the problem examined in this study, it is also important to look at general models of how these resources were obtained. Although northern hunters require more than other hunter/gatherers in the way of fixed facilities and material goods (for example, substantial dwellings, clothes, and tool kits), many arctic groups are characterized by what Lee and Devore (1968:12) have called "Nomadic Style." Throughout the arctic, from resource rich areas such as the north coast of Alaska where at some periods a nearly sedentary life has been possible, to the resource poor areas of the barren grounds where human life was sometimes not possible at all, northern peoples have practiced a seasonal round of subsistence activities with a set of alternative resource attainment strategies which could be implemented when, for one reason or another, one of the major resources failed.

In the Lake Harbour area, as in most areas of the arctic, the majority of resources do not occur in specific micro-environments as they do in some temperate areas. Some locations are more suitable than others for certain resource harvesting activities. Not only the habitat of the animal, but also the technology employed in its capture plays a role in determining these locations. Kemp's (1971) research on modern hunters in the Lake Harbour area has revealed those areas of importance to them (Figure 2). Within these larger areas, there are more specific locations which are of the greatest importance. However, resources are sufficiently dispersed that before the advent of such modern transportation aids as the outboard motor and the snowmobile, it made more sense to move the people to the resource than to move the harvested resource to the people (Kemp, 1971). Therefore, it seems reasonable to assume that some seasonal movmment was part of the economic life of the Dorset population residing in this area.

Under these conditions, the locations of archaeological sites take on significance. Although it cannot be assumed that locations were chosen to maximize one specific resource, it does seem reasonable to assume that some locations were more suitable than others for satisfying resource needs using the strategies suitable for a given season, and that the more suitable site locations were reused frequently. Further, when the availability of resources shifted due to climatic change, the locations used would be expected to shift as well. When such shifts occurred in the past, they do not appear to

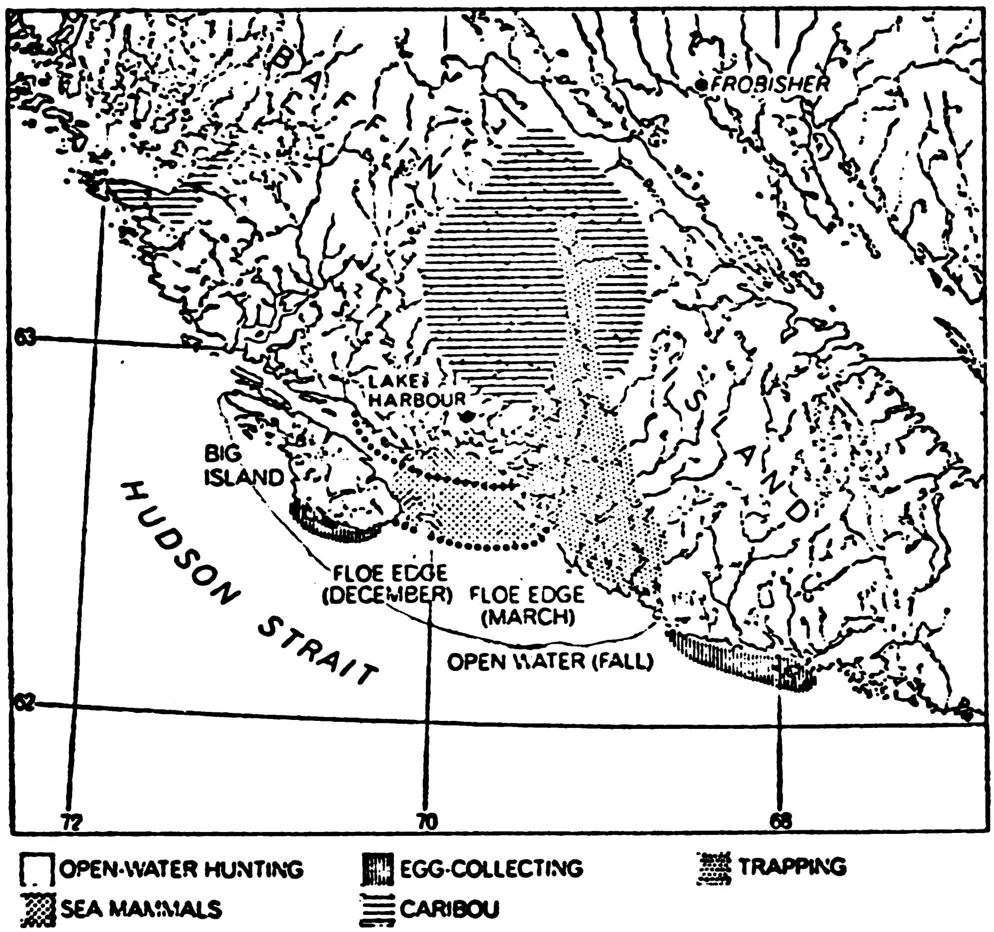


Figure 2. Map of site area showing modern hunting areas and seasonal position of the floe edge. Reprinted with permission from "The Flow of Energy in a Hunting Society " by William B. Kemp.

have brought on major adaptive adjustments. The economy appears to have remained a focal (Cleland, 1966) or an intensive (Dunnell, 1972) one; no major technological innovations occurred. However, settlement pattern change may well have taken place. Whether subsistence pattern change also took place or whether resource change brought on primarily demographic adjustment cannot be demonstrated by this study, although the question is important for future research.

Settlement Pattern, Settlement System, and Subsistence-Settlement System. To help describe the data and shape the explanatory system in a useful fashion, the concepts of settlement pattern and subsistence-settlement system, and the units and relationships associated with them are valuable.[3] Since the discussion of these concepts set out by Rice (1975:57-61) is one of the most useful in the literature, the presentation which follows relies heavily on his work.

Settlement studies, beginning with Willey's (1953) historic monograph Prehistoric Settlement Patterns in the Viru Valley, Peru emphasized the structural and functional, rather than the stylistic, relationships of the data, and hence represented a major departure from traditional archaeology. Two kinds of settlement studies can be distinguished: settlement pattern studies and subsistence-settlement system studies.

Settlement pattern studies (see, for example, Chang, 1962, 1968) are concerned with the structural relationship between classes of settlements or between different classes of parts of settlements. The relationships studied are recorded or described as spatial locations, and settlements may be classified by size, types of structures, styles of artifacts present, and, in some cases, location in the landscape. The result of a settlement pattern analysis is a description which can then be subjected to different kinds of analysis and interpretation.

Unlike settlement pattern studies, settlement system studies (see, for example, Streuver, 1968b; Flannery and Coe, 1968) deal with the functional relationships of settlements to the landscape. System studies are concerned with how the landscape and a human population articulate. Differences in activities or functions are used to determine how this articulation was achieved.

> In pattern studies, the relationship between settlements and the landscape is measured only in terms of the location of one on the other. In system studies the object is to determine the relationship of classes of settlements, in terms of <u>use</u>, to classificatory segments of the landscape. (Rice, 1975:59)

The manner in which a specific group utilized a particular landscape can be described in terms of at least three factors: subsistence technology, scheduling (what activities were performed on a yearly basis), and organization (how the location of activities were arranged in space to complement each other).

The term <u>subsistence system</u> refers to the strategies and activities a population uses to procure resources, particularly food resources. Rice (1975:60) notes that such studies were done in archaeology before the term was invented, although studies based on hard field data are still relatively scarce (Struever, 1968b and Flannery and Coe, 1968 constitute notable examples). One of the reasons that such studies are relatively scarce is that they require large amounts of regionally based archaeological and environmental data. Until quite recently, few areas had been investigated to such an extent that such data were available.

One additional concept, not noted in Rice's discussion, which will be helpful in explaining this problem is the notion of <u>settlement location</u>. A settlement location is a segment of the landscape on which is located a specific segment of the settlement pattern. A settlement location may have within it several site locations which are not necessarily contiguous. Because very little is known about Dorset subsistence, let alone about the subsistence-settlement system, this research makes an important contribution to our understanding of Dorset subsistence by supplying data on the relative importance and the age characteristics of the faunal species identified from faunal samples from two Dorset sites. But this contribution is still a long way from our understanding of the system as a whole. Therefore, the specifics of the Dorset subsistence-settlement system as it existed at the time of the occupation of the Nanook Site cannot play a role in this research. But the concept that there is a functional relationship between the settlement system and the landscape on which it is located is an important concept which can assist in explaining events at the Nanook Site.

In short, the foregoing discussion has set out the models and concepts underlying this research. Precisely how these models function in the explanation of this problem will be delineated further in Chapter 4, which documents the description of the data to be explained and presents the logical system, loaded and fitted with appropriate concepts, for the explanation of the data.

NOTES

1. Dunnell (1971a) uses the terms "classes" for his units and "laws" for his relationships. These terms have been excluded from the definition to prevent the intrusion of issues which are not directly relevant to the discussion.

2. Taylor (1972) has provided descriptive accounts of fauna recovered during his survey between Cape Parry and Cambridge Bay. However, these reports lack much of the information necessary to make them useful for comparative purposes.

3. Parsons (1972) has a good summary of settlement pattern and subsistence-settlement system studies.

CHAPTER 4

THE DESCRIPTION AND THE SYSTEM

INTRODUCTION

Explanation using the pattern model developed by Meehan (1968) requires two basic components, a description of the data in terms of the concepts chosen for use in the research, and a logical system which can be loaded with these concepts and then fitted to the description. This chapter presents both the description (Section I) and the system in both its logical and loaded form (Section II). Fitting the description to the loaded system through hypothesis testing is accomplished in Chapter 5.

SECTION I

THE DESCRIPTION

PART 1

DATING THE SITE

One of the basic questions asked in this research is: Why was the Nanook Site occupied for such a long period of time without notable change? To answer this question, it is important to establish that the Nanook Site was indeed occupied for a period approximating the 500-600 years indicated by the radiocarbon dates. If the site was occupied for a much shorter period, there would be little opportunity for change to be expressed, particularly in an area where change occurs so slowly. Thus, the first part of the description deals with the dating of the site.

A variety of techniques have been used for dating arctic sites. Such techniques have used information from geographic features, for example, beach ridges (Giddings, 1960, 1961, 1966; Meldgaard, 1962) or height above modern sea level (Andrews et al., 1971), from tree rings (Giddings, 1952), or from the formal or informal seriation of artifact styles (Ford, 1959, and others). However, all of these methods have significant limitations.

Some of these drawbacks are obvious. Many arctic sites are not located directly adjacent to the coast, and even if they are, only a few have distinct beach ridges. Most sites are also located north of the tree line. The infrequency with which seriation is used may be due in part to the nature of the data. For example, throughout much of the prehistory of the eastern arctic, stylistic change is extremely slow and gradual, and with the exception of the data gathered by Maxwell (1973) and Meldgaard (1960a&b, 1962) long sequences suitable for seriation are not available. Seriation also may be used infrequently because at least some arctic investigators do not seem to recognize (for example, Taylor, 1968) how data must be structured to do seriation properly (Dunnell, 1970). Because of the limitations involved in these alternative dating methods, the single most powerful tool for dating arctic sites is radiocarbon dating (Rainey and Ralph, 1959; McGhee and Tuck, 1973).

Even though the height of the Nanook Site above modern sea level does provide a gross indication of its age, radiocarbon dating is virtually the only practical means of dating it with any degree of accuracy. Eleven radiocarbon dates produced by three different laboratories on a wide variety of materials are available for the

Nanook Site. These dates are listed in Table 2, along with each date's laboratory number, the Radiocarbon reference for each date, the sample's provenience, and material of which the sample was composed.[1] These dates and their internal relationships are more readily visualized in the graphic presentation of Figures 3 and 4. Figure 3 is a map of the locations in the site from which each of the dated samples was taken. Figure 4 is a graph of nine of the eleven dates, showing the level from which the sample came and the resulting date with its standard deviation. Since two of the dates, GAK-1285 and GAK-1288, are extremely aberrant, they are not included in Figure 4.

In addition to Figures 3 and 4, another useful way of looking at the Nanook C-14 dates is in the form of a dispersion diagram such as Figure 5 (Ottaway, 1973). A dispersion diagram shows all the relevant radiocarbon dates for a cultural entity in a form which emphasizes how the dates are distributed within the period in which they occur. Constructing such a diagram involves ranking the dates by age, dividing them into their respective quartiles, and portraying the results as a bar graph which delineates not only their distribution, but also their median and interquartile range. Aside from providing another perspective from which the dates can be viewed, the dispersion diagram will prove useful later on for illustrating how the radiocarbon dates are affected when correction for various factors influencing the accuracy of the dates are applied.[2]

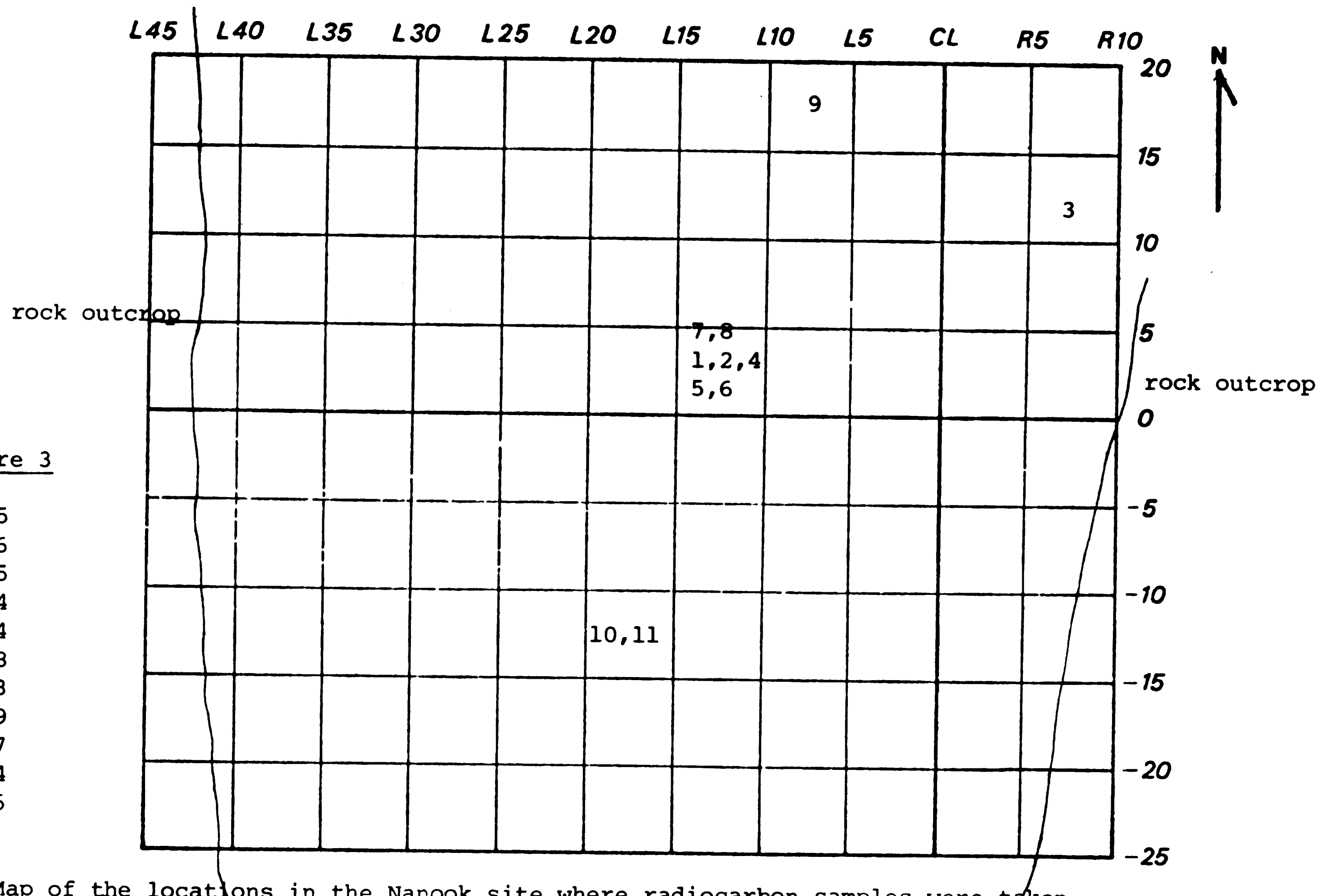
At this point in the discussion it is useful to make two fairly elementary observations about the raw, uncorrected radiocarbon dates. First, it is apparent that the dates range from 2410±120 B.P. (M-1535) to 1827±61 B.P. (P-706), a period of approximately 580 years. This

Table 2. List of the Nanook Site Radiocarbon Dates with Associated Data.

Date #	Date (B.P.)	Provenience Square	Provenience Depth	Provenience Component	Sample Material	Reference
GAK-1285	1400±80	OL15	1.3'	9-3	sterile buried sod layer	(Kigoshi, et al., 1969:313)
GAK-1286	2370±100	OL15	1.2'	9-3	willow twigs	(Kigoshi, et al., 1969:313)
M-1535	2410±120	5R5[1]	1.0'	9-1	charred animal fat cementing sand grains and pieces of seal skin	(Crane & Griffin, 1966:278-279)
GAK-1284	2380±80	OL15	1.0'	9-3	seal skin, caribou skin and other organic matter	(Kigoshi, et al., 1969:312,313)
GAK-1494	1870±80	OL15	1.0'	9-3	sod	(Kigoshi, et al., 1973:49)
GAK-1288	580±80	OL15	1.0'	9-3	willow twigs	(Kigoshi, et al., 1969:313-314)
GAK-1493	2010±80	OL15/5L15[2,3]	.9'	9-3	charred fat (seal?)	(Kigoshi, et al., 1973:49)
GAK-1279	2220±100	OL15/5L15[1,2]	.8'	9-3	sod	(Kigoshi, et al., 1969:312)
GAK-1287	2110±80	15L10	.5'[4]	9-3	whale baleen	(Kigoshi, et al., 1969:313)
P-704	1916±61	-15L20[1]	.3'	9-2	dried sod and grasses associated with animal skins and other organic matter	(Stuckenrath, et al., 1966:363)
P-706	1827±61	-15L20[1]	.3'	9-2	willow twigs associated with animal skin and other material dated by P-704	(Stuckenrath, et al., 1966:363)

1. No square given in original Radiocarbon reference.
2. Square designation is misprinted in original reference.
3. Balk between two squares indicated.
4. Depth is misprinted in original reference. Printed as 5' instead of .5'.

KdDq-9, The Nanook Site
Baffin Island, N.W.T.
Canada



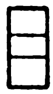
Key to Figure 3

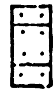
1. GAK-1285
2. GAK-1286
3. M -1535
4. GAK-1284
5. GAK-1494
6. GAK-1288
7. GAK-1493
8. GAK-1279
9. GAK-1287
10. P - 704
11. P - 706

Figure 3. Map of the locations in the Nanook site where radiocarbon samples were taken.

Key to Figure 4

 sod

 baleen

 charred fat mixed with sand grains and other organic matter

 willow twigs

 charred fat (seal?)

 seal skin, caribou skin and other organic matter

DCA - degree of certainty of association

A. Full certainty: the archaeological object itself furnished the measured sample.
B. High probability: there is a direct functional relationship between the organic material which is measured and the diagnostic archaeological finds.
C. Probability: there is no demonstrable functional relationship between measured sample and archaeological material, but the quantity of organic material and the size of the fragments argue in favor of a relationship.
D. Reasonable possibility: as C, but the fragments are small and scattered.

ADC - age differential class

A. The difference in date is so small as to be negligible (less than 20 years).
B. The time difference can amount to several decades (from around 20 years to 100 years).
C. The time difference may amount to centuries (more than 100 years).
D. The time difference is not precisely known.

(This figure and its key follow closely the illustrations suggested and used by Waterbolk (1971)).

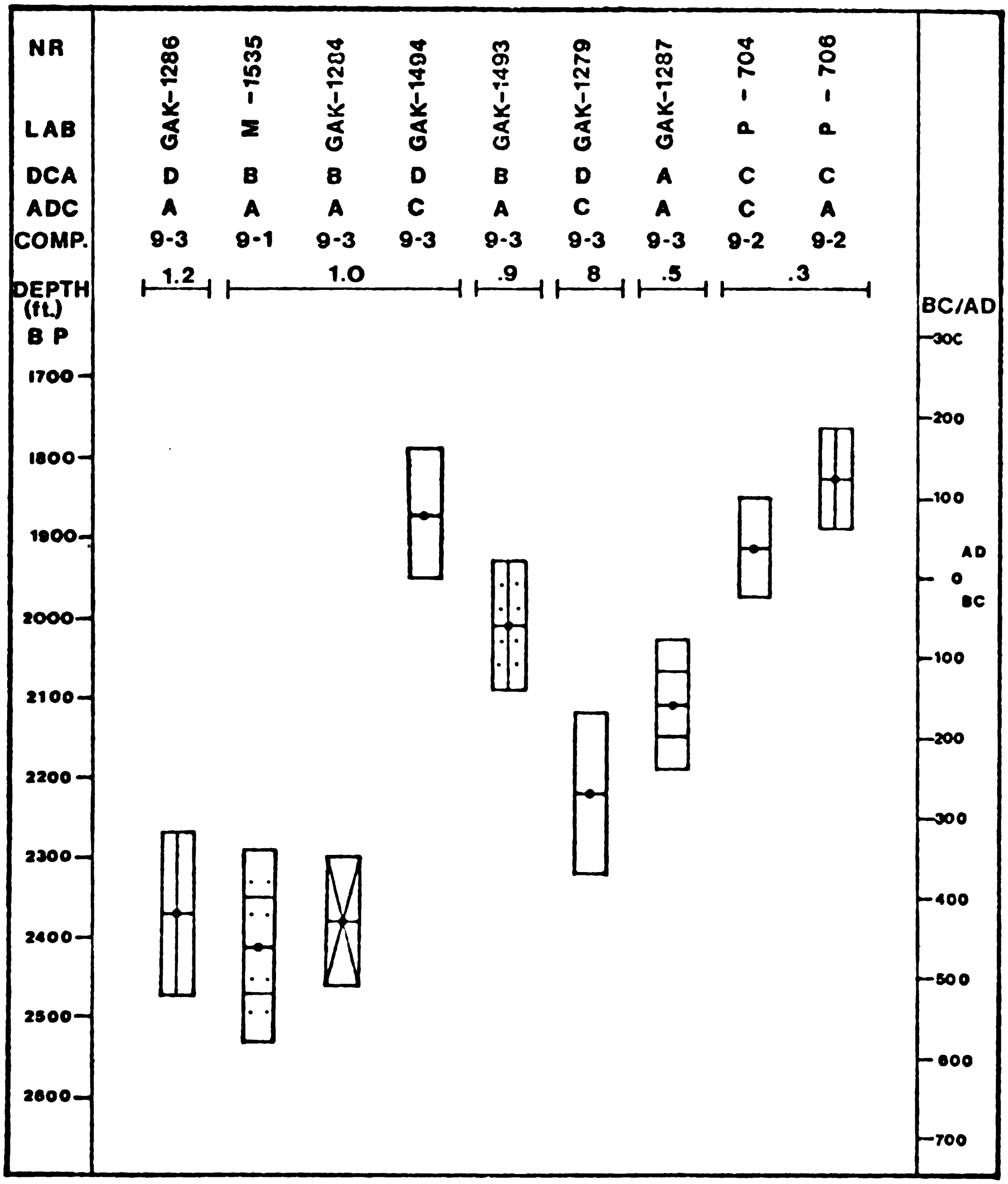
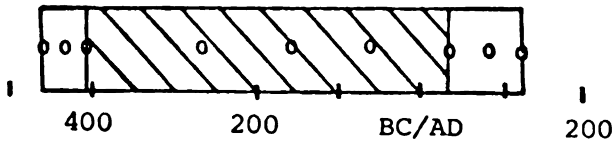


Figure 4. Nanook Site radiocarbon dates. Based on technique from Waterbolk, 1971.



Data on which Figure 5 is based.

Ranked dates - 1.1827
2.1870
3.1916
4.2010
5.2110 - median
6.2220
7.2370
8.2380
9.2410

interquartile range

Figure 5. Dispersion diagram of the Nanook Site radiocarbon dates.

period is only an estimate, since each radiocarbon date has a standard deviation based on the statistical error implicit in the random nature of the radioactive process itself. The standard deviation indicates that the actual date has approximately a 60% chance of lying within the time interval indicated so that the actual time span of the site may be somewhat greater or less - - 580 years is merely the best statistical estimate which can be made from the raw data.

Second, if the radiocarbon dates are interpreted in terms of the principle of superposition, seven of the nine dates shown in Figure 5 are consistent, the two exceptions being GAK-1493 and GAK-1494. GAK-1494 is clearly too late for the depth at which it occurs, especially given the other three dates for samples from the same or a greater depth (1.0' and 1.2'). GAK-1493 presents a very similar, though not as serious, problem. Several possible causes for these inconsistencies will be discussed in Chapter 5.

Using the remaining dates, however, there would seem to be enough compatible evidence to show that the occupation of the site spanned an interval of time sufficient to demonstrate change, if change occurred. Nevertheless, the inconsistencies represented by those dates which do not fit our expectations raise the question of why such dates occur. The accuracy of radiocarbon dates is influenced by variability in a number of factors, some of which are clearly understood and can be dealt with using simple corrections, and some of which, as yet, present major unknowns. The nature of the various kinds of variability and how they affect the site's dates will be discussed in Chapter 5. However, because much of the recent work in paleoclimatic studies, which will be discussed next, is based on uncorrected radiocarbon dates, for the present the site dates have been left in the same uncorrected form for the sake of comparability (Waterbolk, 1971).

PART 2

CLIMATIC CHANGE

The second basic question asked in this research is Why was the Nanook Site finally abandonned? It was established in Chapter 3, where the model of the Arctic Ecosystem was discussed, that populations living in arctic areas are particularly sensitive to oscillations in their physical environment. One of the more prominent perturbations which can bring about change in the ecosystem is climatic change. Because changes in climate can have a significant effect on the nature of the relationship between resources and human subsistence, it is important to examine what is known about climatic change for the region and time period of interest. There is no climatic change information available which is specifically related to the area of the Nanook Site, so that the only appropriate alternative is to examine broad climatic patterns for a large geographic area, and attempt to relate these patterns to the local situation.

Accordingly, this section is a discussion of the evidence for climatic change for northern North America and adjacent parts of the Northern Hemisphere. The following section relates these broader climatic patterns to the Nanook Site and its immediate surroundings. The goal of this discussion is to document the climatic events affecting the eastern arctic from 2500 B.P. to 1500 B.P., and thereby provide a sound basis for the conclusions about climatic change which serve as important elements in the explanation.

INITIAL CONSIDERATIONS

Existing climatic outlines and the problem of dates. Three archaeologists, Dekin, Fitzhugh, and McGhee, all of whom are interested in the relationship between climatic change and cultural change in the eastern arctic, have proposed an outline of climatic events (Figure 6) for all or part of the area for approximately the past 5000 years (Dekin, 1969, 1970, 1971, 1972; Fitzhugh, 1972; McGhee, 1972). While the climatic regimes outlined by these authors are broadly similar, they are formulated on different bases. On the one hand, Dekin and Fitzhugh (whose outline is based in part on Dekin's research) draw on the literature of disciplines outside archaeology to formulate an outline of climatic events. Then they use this outline as a tool in explaining why certain changes occur at given times in their cultural sequences. Both find confirmation of their climatic outline in the cultural sequence, but such confirmation is, of course, independent of their primary sources of information on climatic events.

On the other hand, McGhee draws on the cultural record itself as a source of data in formulating an outline of climatic change. For example, as evidence of support for a cooler period after 2500 B.P., McGhee cites "the scarcity of occupation sites dated to this period (2500-1900 B.P.), the absence of marked cultural uniformities over wide areas, and the apparent abandonment of the eastern High Arctic,... (McGhee, 1972:52)." Unlike Dekin and Fitzhugh, McGhee begins his analysis with an outline of cultural events in the eastern arctic from which he then infers support for a sequence of climatic events based on non-cultural data.

The significance of this difference in approach lies in the kind of

Fitzhugh			Dekin			McGhee
PERIOD	CLIMATE	DATE BC/AD	STAGE	CLIMATE	DATE BP	CLIMATE
		1900				
				Cold	100	
	Little Ice age					Cold
VIII						
	Colder oscillations	1500				
			VIII		500	
	Forest retreat					Continued warm
					800	
			VII	Much warmer		Warm
	Second northern forest maximum	1000			1000	
VII						
	Continued warm			Slightly colder wetter		
	Forest moves north		VI			Cooler
	Cool episode but not cold	500				
					1600	
VI	Sharp warming trend Dry					Warmer
		AD	V	Warmer	1900	
		-0-				
		BC				Cold
	Prolonged cold and wet			Cold		
		500	IV		2500	
						Warm, stable
IV	Cooling continues wetter					
					2800	
			III	Warm		Warmer
	Gradual cooling wet	1000				
III					3100	
	Cooling begins					Colder, unstable winters
			II	Cold unstable?		
	Widespread forest retreat	1500				
					3600	
	Maximum northern extension of forest			Warm		Warmer in the North
			I			
		2000			4000	
II	Oscillations Generally warm Cooling Warm and dry					
		2500				

Figure 6. Comparison of three climatic outlines.

conclusions which can safely be drawn using these outlines. An explanation of cultural changes based on McGhee's outline alone stands in some danger of becoming a circular argument because the cultural evidence to be explained might not be sufficiently independent of the primary data used to construct the climatic outline. In addition to this major difference in approaches, each scheme was intended for a slightly different geographic area, each researcher based his outline on a somewhat different set of references on climatic change, and each one failed to consult some areas of research which might have contributed to a fuller picture of the climatic events under consideration.

Despite these basic differences in the three schemes, they are useful in that taken together, they pinpoint the main problem in understanding climatic change between 2500 B.P. and 1500 B.P. Specifically, this period seems to have been characterized by an initial colder episode which lasted for approximately the first half of the millenium. These colder conditions were followed by a somewhat warmer episode.[3] The problem arises because the three schemes give different dates for the onset of this warmer period.

The problem of differences in dates comes about, in part, because the second half of this millenium has been much less extensively studied and documented than the first half (Bryson, verbal communication, 1974; Bryson and Wendland, 1967; Porter, verbal communication, 1974). Less may be known about this period because it does not stand out as a marked, abrupt change from preceeding centuries. Additionally, warming trends tend to bring less catastrophic changes than cooling trends, so that evidence of the onset of a warmer period may be less definite, slower to appear, and hence harder to index through research.

Because it is difficult to determine from these existing outlines when this crucial change took place, and because there have been some valuable new supporting data published since the Dekin, Fitzhugh, and McGhee schemes were formulated, it is worthwhile to construct an up-to-date set of evidence on broad scale climatic change.

Potential problems in data interpretation. Before beginning this discussion of paleoclimatic evidence, it is important to recognize that terms such as "warm" and "cold" are relative and that the use of such terms represents a much-simplified, heuristic characterization of the periods in question. Clearly, for many purposes it is necessary to avoid characterizing a climatic event by a single parameter such as temperature (Bryson and Wendland, 1967). Change in the patterns of precipitation, temperature, wind, and cloud cover, as well as other factors, also occur between different climatic episodes. In addition, the specific nature of these factors must frequently be related to geographic and climatic features of a given location, e.g. proximity to a large body of water or position relative to a major frontal system. In the discussion which follows, an effort will be made to tailor the scope of the characterization of the climatic episode to the scope of the geographic unit under consideration. For example, when large geographic areas are discussed, the characterizations will be broad and more general; when examining the local situation the characterizations will be more detailed and specific.

In discussing paleoclimatic events, it is also helpful to recognize that differing underlying assumptions about the general character of climatic change affect the outcome of research. Since the early work of Antevs (1948, 1952, 1955) and others, it has been assumed that climatic

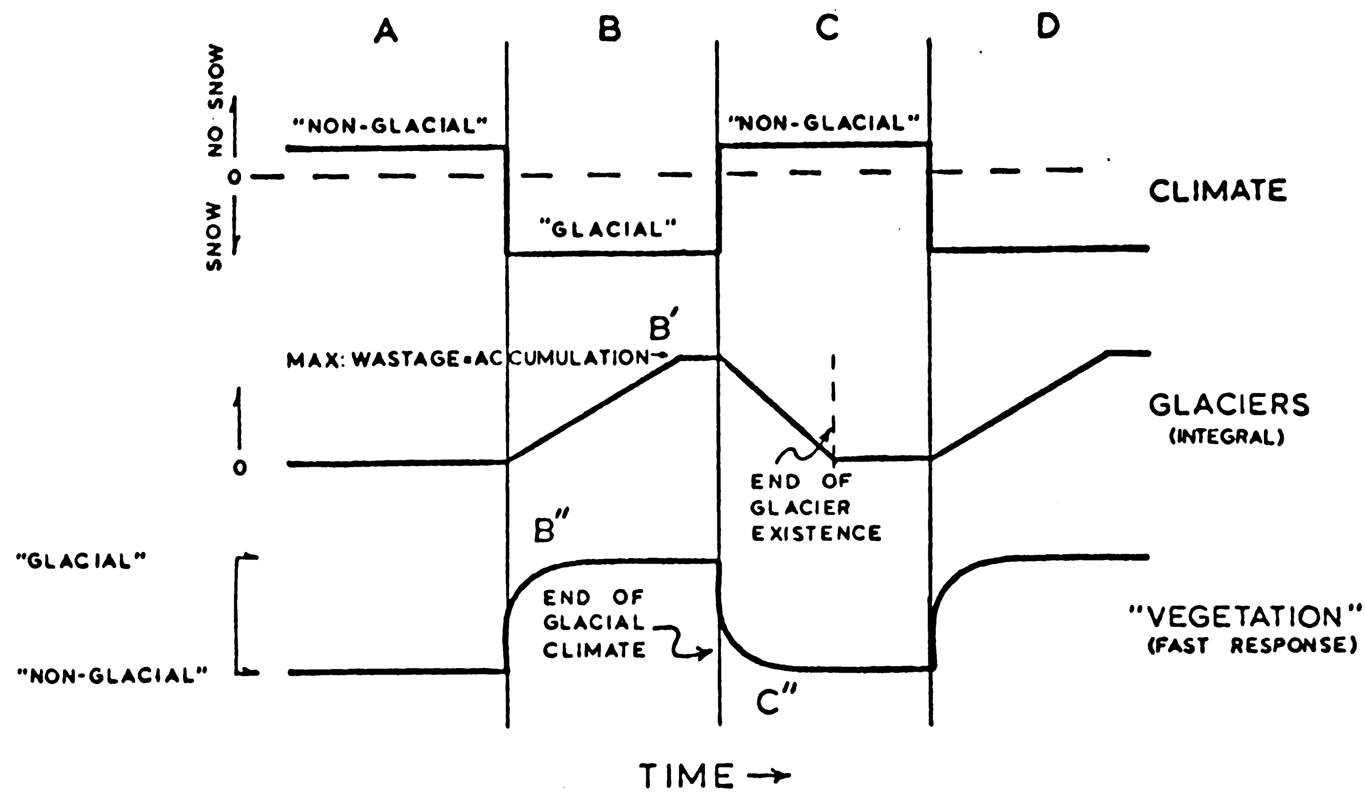


Figure 7. Step-wise model of climatic change. Shows suggested glacial and vegetative response to abrupt temperature changes with time. Reprinted with permission from Bryson and Wendland, 1967.

change was a slow, gradual process. While this model of the change process has proven useful for some time, Bryson and Wendland (1967) have suggested that its productive life may be over. They have proposed an alternative model of climatic change based on a step-wise model in which change takes place rather rapidly and abruptly. Thus, instead of assuming long, gradual change, they assume that longer quasi-stable periods are interspersed with quite short periods of marked instability. Figure 7 is a graphic presentation of their alternative model. In the course of examining the evidence in this section, it will be helpful to keep this model in mind.

In addition to these points, there are other complex problems involved in understanding climatic change in the past. First, the researcher must use data from a variety of research disciplines. In some respects, this is an advantage because the opportunity for independent confirmation of a particular finding is increased. However, the difficulties involved in accurately relating data based on quite different processes and derived from diverse sources must also be overcome. For example, does an increase in pine pollen concurrent with the retreat of a glacier indicate the same climatic event? Second, the researcher must deal with the question of what kind of climatic change can legitimately be inferred from a particular climatically-related phenomenon (Bryson and Wendland, 1967). For example, is the onset of glaciation in a given area indicative of falling mean annual temperatures of increasing fall and winter precipitation?

Third, the researcher needs, but often does not have, an accurate indication of the lag time involved between the occurrence of the indicator and the occurrence of the climatic event. For example, movement of treeline and movement of the mean summer location of the arctic front seem to be coordinated with major warming and cooling trends. But, after the arctic front has moved farther north, how long does it take for the forest to regrow so that once again treeline and the arctic front are coincident?

And fourth, the researcher must sort out which data are applicable to different geographic areas. Some aspects of climatic change can be dealt with successfully in terms of world-wide trends; others must be understood in terms of local climatological phenomena. It is often difficult for the nonspecialist to select an appropriate model of significant climatological relationships with which to interpret data relevant to a localized area. The example involving the arctic front is a case in point. All of these data problems must be taken into consideration in the examination of the evidence for climatic change which follows.

Most of the significant data about climatic change results from research in the quaternary sciences and these data will furnish the base for the discussion in this section. Several specialized fields have made important contributions to current knowledge of past climatic events: glaciology and glacial geology, palynology and paleobotany, the study of eustatic changes in sea level, and prehistoric movements in the location of treeline, analysis of the growth rates of marine bivalves, the calcium carbonate rations in ocean bed cores, and the oxygen isotope ratios in the Greenland ice core, as well as the construction of broad climatic/atmospheric models of temperature, air pressure wind movement patterns in the past. The following parts of this first section consider what the data from each of these specialized areas of study contributes to current understanding of climatic change in the eastern arctic between 2500-1500 B.P.

EVIDENCE OF CLIMATIC CHANGE

Evidence from glaciology and glacial geology. Of all the sources of information on climatic change, evidence of glacial advances and retreats is among the most readily understood. However in contrast to this popular view, the ability of glaciology and glacial geology to provide the archaeologist with temporally-specific data on climatic change is somewhat limited. As glaciologists clearly warn, climatic change is not the only factor which may be responsible for the movement of glaciers (Goldthwait, 1966; Meier, 1965; Porter, 1971; Porter and Denton, 1967). Quite apart from the effects of climatic change, the overall size of a glacier, its load, and the topography of its bed may play major causative roles in the course of glacial events. Thus, even in one local area all the glaciers will not respond to a climatic event at the same time or in the same manner. Only the movement of a number of glaciers from widely dispersed areas can be taken as indicative of climatic change. However, on the positive side, climatic change sufficient to provoke such widespread glacial movement will undoubtedly be of broad scale and should be confirmable with data from one or more of the other sources mentioned above.

Once the evidence for widespread glacial movement has been established, there is still a need for attention to the problems and sources of error inherent in the various dating methods used, such as radiocarbon dating (Butzer, 1971), lichenometrics (Beschel, 1961; Miller, 1973), and various forms of indirect dating. Since many dates are maximum or minimum limiting dates for an event, care must be taken to consider

exactly what aspect of a glacial event a date denotes. Carelessness in the interpretation of dates can lead to false correlations and inaccurate conclusions. A similar problem arises when different dating methods are used to date the same event. For example, as illustrated by Miller (1973) and shown in Figure 8, lichenometry on the rock surface of a moraine and radiocarbon dates on buried organic material within the same moraine may yield quite different dates, both of which are accurate because they involve different processes in moraine formation. Hence interpretations based on a mixture of dating techniques may prevent the investigator from seeing important relationships, if this potential problem is not taken into consideration. If an archaeologist is to make the best use of the glaciological literature, he or she must also keep these potential pitfalls in mind.

During the late thirties and early forties, Mathes published the initial summaries of evidence for post-Wisconsin glacial advances. Since then, extensive research, some of it in key remote areas, and new dating techniques have provided a wealth of new information on the subject. To date, one of the most useful summaries of recent Holocene glacial activity is an article by Porter and Denton (1967). Porter and Denton brought into common usage the term Neoglaciation which they define as a geologic/climatic unit denoting, "the rebirth and/or growth of glaciers following maximum shrinkage during the Hypsothermal interval (Porter and Denton, 1967:181)."

Examining the chronology of Neoglaciation in the North American Cordillera, they conclude that major, widespread Neoglacial advances occurred throughout the area, culminating 2600-2800 years ago. Their conclusions are based on numerous carefully interpreted radiocarbon

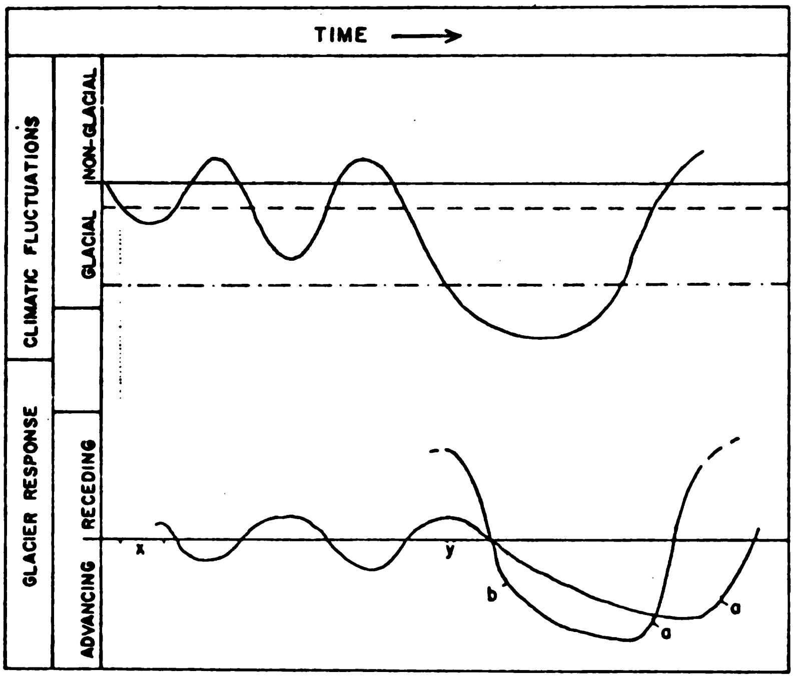


FIG. 9. The response of low and high latitude glaciers to climatic fluctuations. Arctic glaciers are more sensitive to minor climatic fluctuations, but have a longer response time (x) than do southerly glaciers (y). The difference in the apparent age of a moraine dated lichenometrically (a) and by organics overridden or incorporated in till (b) is large.

Figure 8. Curves showing differential response to the same glacial event. Reprinted with permission from Miller, 1973. Copyright (1973) University of Washington.

dates, and other evidence from a variety of latitudes and situations. While the authors' main focus was the North American Cordillera, which they declared to be the type area for Neoglaciation, they noted information from several other areas around the world which indicated that the observed Neoglacial advance was not confined to that area. They found that lichen studies in arctic Canada suggest that early Neoglacial moraines there were built about 2400 years ago, while similar moraines in West Greenland probably also date from the third or fourth millenium B.P. Several dates from the Alps similarly yield maximum limiting ages for early Neoglacial advances comparable to those from western North America. There is also evidence of periglacial activity in Australia which began about 3000 years ago and was essentially contemporaneous with Neoglacial ice advances in western North America. In a later 1970 paper, Denton and Porter reaffirm their earlier conclusions that 2600-2800 B.P. encompassed the peak of glacial activity. Denton and Karlen (1973), on the basis of their studies in the St. Elias range of western Canada and in two mountain ranges of Swedish Lapland, as well as more broadly based data, likewise conclude that the period of intense glacial activity began about 3300 B.P. and lasted until about 2400 B.P.

According to Porter and Denton, after this period of activity, "a long era of milder climate followed, during which most of the glaciers probably diminished in size (1967:177)." In their 1970 study, the authors state that various evidence from areas bordering the North Atlantic suggests that a relatively mild climate characterized most of the long interval between the 2800-2400 B.P. advances and the "Little Ice Age" events of the past four centuries. In particular, they mention evidence of a milder climate at the beginning of the Christian era in Iceland and evidence from bogs in western Norway which suggests that 50-400 A.D. was a period of warmer climate in Scandinavia as well. In this context, it is helpful to note Figure 9 which appears in both the 1967 and 1970 summaries by Porter and Denton.

While the vast majority of available data fit the pattern summarized above, there are some notable exceptions. Some of these exceptions involve dates which are not too far from the expected. For example, Porter and Denton (1967) cite radiocarbon dates from the southern hemisphere which seem to indicate that a major glacial advance culminated there between 2300 and 2000 B.P.

In summarizing the results of research in the Muir Inlet area of Glacier Bay, Alaska, and the Icefield Ranges of the St. Elias Range of western Canada, Goldthwait (1966) found, despite the difference in precipitation regimes, that Neoglacial advances took place in both areas during the same time period. On the basis of radiocarbon dated wood embedded in key strata, as well as other evidence, Goldthwait concludes that the expansion of virtually all the local glaciers in both regions took place between 2750 B.P. and 1650 B.P. This pattern partially overlaps the one which Denton and Karlen describe for the St. Elias and differs from the expected pattern only in its terminal date.

However, other exceptions to the Denton and Porter pattern present more serious contradictions. In direct contrast with this pattern, Benedict (1973) reports that the period from 3000-1850 B.P. in the Front Range of the Colorado Rockies is nonglacial in character. Both lichenometric and radiocarbon dates were used to date the Audubon Glacial Stage between 1850 and 950 B.P. It should be noted, however,

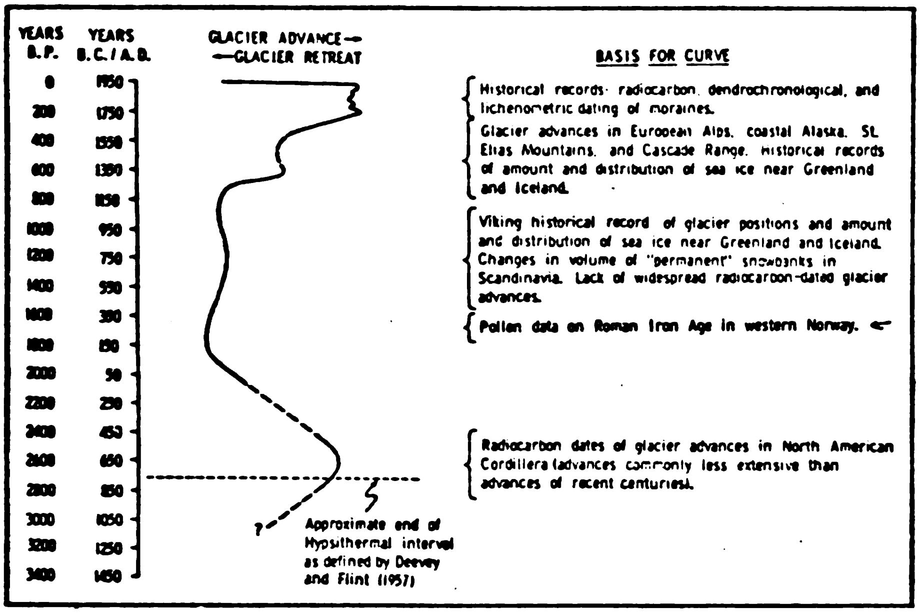


Fig. 4. Generalized curve of glacier fluctuations during Neoglaciation (dashed where data are poor or lacking). Most information from alpine areas (see text for sources). Horizontal axis has no absolute scale: total known Neoglacial advance ranged from more than 15 miles for Kaskawulsh Glacier and possibly more than 60 miles for ice in Glacier Bay to less than a mile for some small Scandinavian and Cordilleran glaciers. Although the curve probably reflects the general situation, for an individual glacier any of the Neoglacial advances may have been the most extensive. A possible early Neoglacial advance close to 4700 years ago has purposely been omitted because its regional significance is still somewhat obscure.

Figure 9. Generalized curve of glacier fluctuations during Neoglaciation. Reprinted with permission from Porter and Denton, 1967.

that Benedict's dates generally represent minimum limiting dates. Further, he is uncertain whether the Audubon advances include two or three advances and readily admits his secondary fluctuations are poorly dated. Nevertheless, Benedict feels his overall glacial chronology for the area (including the period of interest here) correlates well with the local pollen evidence and thus supports his conclusion that climatic conditions are responsible for the unusual pattern of glacial activity in the Front Range. Benedict also feels his findings serve to contradict Porter and Denton's concept of fairly synchronous behavior on the part of North American glaciers during the early Neoglacial period. However, Benedict's uncertainty about some of his dates, as well his lack of bracketing dates for the Audubon Advance prevent his data from presenting a serious challenge to the existence of a pattern.

Potentially, the most crucial source of contradictory evidence comes from Baffin Island itself. In the course of extensive glaciological and geological research over broad areas of northern and central Baffin Island, J.T. Andrews working with numerous graduate students and associates from INSTAAR (Institute of Arctic and Alpine Research, University of Colorado) has documented at least two locations with potentially contradictory evidence. The first of these, the Barnes Ice Cap, shows evidence along its western margin of a major glacial advance which Andrews (1970) has called the King Phase, and has dated at approximately 1700 B.P. This date is based primarily on lichenometrics (Andrews and Webber, 1964) and is a minimum limiting date. The King Phase is preceded by a period of minor fluctuations in the extent of glacierization[4] of the area, but it appears to be the first major advance of the ice cap margin after the Flint Phase which has been dated at about 5000 B.P.

The second Baffin Island location producing potentially contradictory evidence is the Cumberland Peninsula on the east coast. Miller (1973) has constructed a glacial sequence based on lichenometric dates for moraines of several glaciers in the area, as well as a summer paleotemperature curve based on radiocarbon dates associated with various buried organic layers. He finds the two curves agree quite well, both with each other, and with a similar curve based on pollen evidence from elsewhere in arctic Canada (Figure 10). He concludes from his data that a glacial episode came to an end in that area just prior to 1600 B.P.

Andrews, Miller and other members of the INSTAAR group have sought an explanation for this glacial activity which is out of sequence with the rest of North America. An explanation has been forthcoming, in part because this is not the only period at which glaciation in northern and eastern Baffin Island is out of phase. From perhaps as early as the onset of the Wisconsin, glacial movement in this area seems to be most prominent at the beginning and at the end of major glacial episodes, while at the heighth of such episodes, little activity seems to have taken place (Andrews _et al._, 1972a&b; Andrews and Ives, 1972; Andrews _et al._, 1974; England and Andrews, 1973).

Their explanation begins with the recognition that Baffin Island as a whole, and the Cumberland Peninsula in particular, lie very close to the glacial limit (Andrews _et al._, 1972a). A considerably smaller variation in the temperature or precipitation regime than would be required at lower latitudes is necessary to change from a nonglacial to a glacial mode. A difference of perhaps only 1-2°C in summer

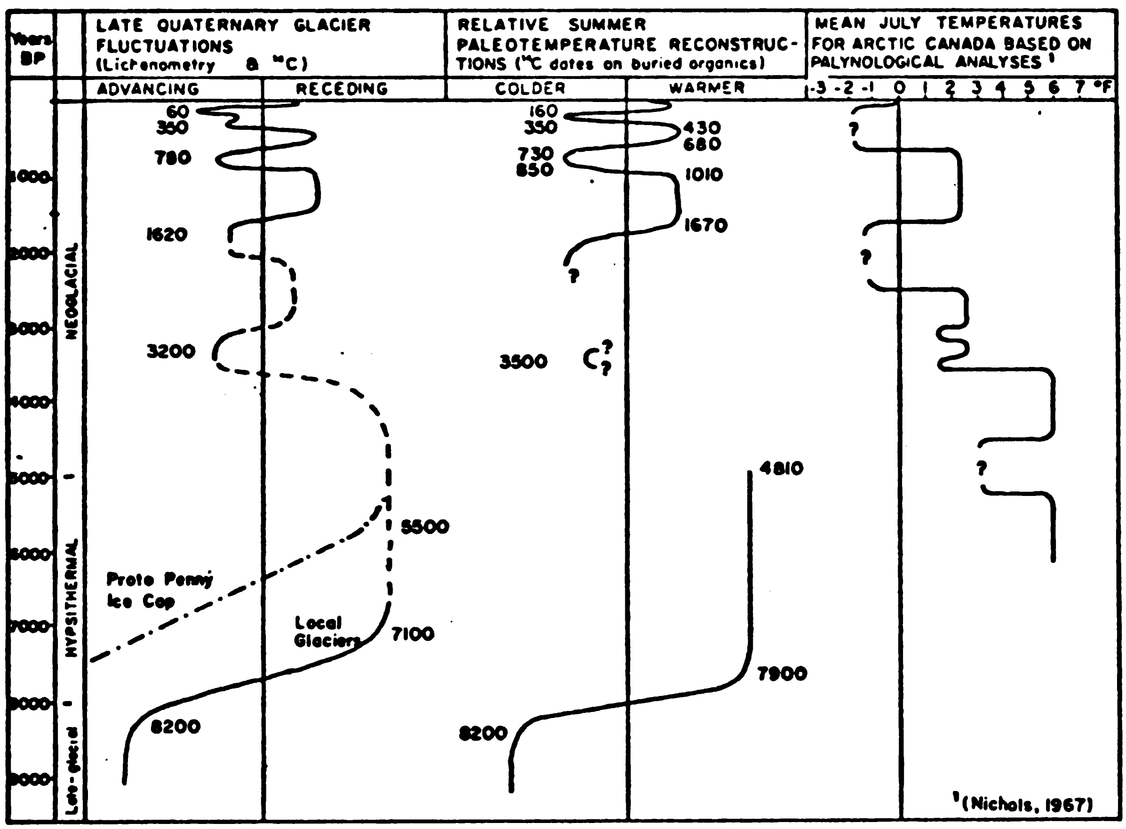


FIG. 11. Comparison of glacier fluctuations as determined lichenometrically (Fig. 10) and by ¹⁴C, summer paleotemperature reconstructions from ¹⁴C dates on buried organic horizons and mean July temperatures for Arctic Canada based on palynological analyses of Nichols (1967). The close agreement between the three curves reinforces the conclusions of this paper.

Figure 10. A comparison of data garnered from several different paleoclimatic sources. Reprinted with permission from Miller, 1973. Copyright (1973) University of Washington.

temperature might determine whether precipitation fell as snow or rain. Summer snowfall replacing rainfall would make a marked difference in the albedo and hence in the pattern of ablation. The Cumberland Peninsula has more snow annually than almost any other area of Baffin Island making it particularly susceptable to this kind of change (Bradley, 1973a; Bradley and Miller, 1972).

In the course of observing weather conditions on the eastern coast of Baffin Island over the past ten years, Bradley and Miller (Bradley, 1973a; Bradley and Miller, 1972; Miller, 1973) have noted several interesting changes. During this period average summer temperatures have dropped 1.2°C, but average winter temperatures have increased 2.0° C, and the mean annual temperature has also increased. At the same time, fall and winter precipitation in the form of snow has shown a marked increase. The result has been a very noticeable increase in glacerization in the Cumberland Peninsula area over this period.

Drawing on several recent computer-based climatic models of events during and immediately following the Wisconsin period (Barry et al., 1971; Barry, 1973; Lamb, 1971; Lamb and Woodruffe, 1970), as well as the information about recent climatic events on the Cumberland Peninsula, Andrews and some of the other members of the INSTAAR group have proposed their own model of glacial behavior for this area which attempts to explain why glacial movement is out of phase (Andrews et al, 1972a; Andrews et al., 1974; Andrews and Ives, 1972). According to their model, the slight summer cooling which might well accompany a preglacial period would lower summer ablation, aid in the increase of fall and winter precipitation, and bring about the onset of glacial conditions in this area prior to their advent elsewhere, particularly at lower latitudes. However, once the glacial period was in full swing, temperatures would become lower, precipitation would decrease, and glacial activity on Baffin Island would generally cease due to a lack of necessary snow fall. However, at the end of a glacial period, as temperatures again became warmer, precipitation would again increase, and glacial activity in these areas would resume, even though elsewhere it had ceased.

Preliminary evidence going back as much as 120,000 years from both Ellesmere Island (Pheasant and Andrews, 1973) and Baffin Island would seem to confirm this theory. Data from Greenland can also be interpreted as lending some confirmation. There Ten Brink (1971, 1972) has found evidence of a period of unusually high hydrological budget at about 1860 B.P. Weidick (1968) and Ten Brink date the second inner Moraine advance as presumably 2500-2000 B.P. and tentatively correlate it with the King Phase, as well, although the dating seems rather tentative for concrete conclusions.

It is interesting to note that Ten Brink and Weidick differ with Andrews and the INSTAAR group on what causes the shift from nonglacial to glacial conditions. Ten Brink and Weidick see a lowering of mean annual temperature as a key factor. They cite historical records in which such a temperature change has preceded by a few decades virtually every historically recorded glacial advance in western Greenland. Andrews and the INSTAAR group on the other hand, give primacy to increased precipitation, particularly during the fall and winter months. As evidence, they cite the recent record in which average yearly temperature has risen, but glacierization has set in. If Ten Brink and Weidick used mean summer temperature rather than mean annual temperature they might be forced to agree to some extent with Andrews and his colleagues, for a cooling of the mean summer temperature appears to be an integral part of the increased precipitation model (Miller, 1973).

Thus, from the glaciological evidence summarized by Porter and Denton and others, there emerges a picture of widespread glacial advance which reached its peak between 2800 and 2600 B.P. followed by a more moderate climatic episode, the effects of which were felt by about 1900 B.P. Some conflicting data from areas such as southeastern Alaska and the bordering Yukon Territories and the Front Range of the Rockies remains unexplained. There is also conflicting data for Baffin Island; however, if the INSTAAR group's model of glacial and climatic events for Baffin Island is valid, the conflict between events in that area and the general pattern for the rest of North America is more apparent than real. That is, while the glacial episodes on Baffin Island and for the rest of North America are out of phase, they nevertheless provide consistent information about climatic conditions during the period of interest.

Evidence from eustatic sea level change. An area of research closely related to glaciology is the study of eustatic changes in sea level rise due to the increasing amount of water released to the oceans by melting glaciers. It is important to recognize at the outset that there has been considerable controversy concerning the validity of research findings in this field relative to climatic change. First, until recently it has been very difficult to separate the effects of eustatic sea level rise from isostatic rebound or the rise of the land due to the melting of the Laurentide Ice Sheet or similar large, heavy ice bodies. Since both processes have been going on simultaneously since the end of the Wisconsin, their mutual effects are not easy to sort out in any given location. Second, there is considerable debate over how accurately minor climatic fluctuations are registered by the strandlines which mark eustatic transgressions (for elaboration of these issues and their proponents see Jelgersma, 1966). However, several researchers, including Mörner (1969, 1971), Binns (1972), and Andrews and his colleagues, feel they have overcome these difficulties successfully, and conclude from their research "that strandlines reflect climatic controls and are an index of Holocene climatic variation (Andrews et al., 1972b:149)." The agreement between these results and the pattern which would be expected if the INSTAAR climatic model for Baffin Island glacial activity makes it worthwhile to examine their results.

For the period under consideration, Mörner (1969) in his research on southwest Swedish coastlines, and Binns (1972) in his work in the British Isles and in his summary of work from Svalbard, Norway and elsewhere note that a strandline marking the onset of climatic deterioration about 2500-2400 B.P. is clearly recognizable. Andrews and his colleagues attempt to use this data to support their proposition that the Baffin Island region cannot be fitted into existing glacial chronologies. They show that the major strandlines along the east coast of Baffin Island are dated at 2800 and 2000 B.P., dates which are out of phase with the European sequence of strandlines. If strandlines are indeed indicative of glacial activity in a given area, these dates (and the second one, in particular) would confirm not only their hypothesis that glacial movement in the Baffin Island area is out of phase with much of the northern hemisphere, but also the sequence of climatic events expected on the basis of Porter and Denton's glacial summary.

Evidence from the Greenland Ice Core. Another potential source of climatic information closely related to glaciological research is the climatic record from the Greenland Ice Core. To obtain this core, a bore hold 1390 meters deep was drilled in the Greenland Ice Cap 225 kilometers east of Thule (Dansgaard *et al.*, 1969). Samples of ice taken from this core were analyzed for the ratio of 0^{16} to 0^{18}. Changes in this isotopic ratio are indicative of differences in the temperature at which the original snow in the ice cap fell. Profiles of these isotopic changes in the core can provide a profile of past climatic changes, provided that too many non-climatic factors have not influenced the isotopic ratio.

When the early results from oxygen isotope ratio studies were published in 1969 (Dansgaard *et al.*, 1969), the technique appeared to be the best tool yet devised for deciphering climatic change. All three archaeologists relied on this 1969 profile in formulating their outlines. The results appeared clear-cut and in fairly close agreement with existing data. Since then, however, more intensive analyses have been performed and more detailed profiles have been constructed (Johnson *et al.*, 1972; Dansgaard *et al.*, 1971). These more complete data have proved less definitive, at least for the period of primary interest here (Figure 11).

While the later Holocene ratios are not as troubled by the dating problems which plague the earlier parts of the core (Anonymous, 1972; Dansgaard and Johnson, 1969; Weertman, verbal communication, 1973), the entire ratio profile is still dated only by relative means, based on a physical model of accumulation and flow of the ice cap. Furthermore,

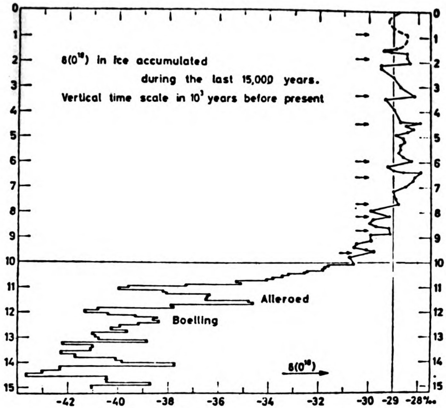


Fig. 4. Climatic variations reflected by δ(O18) variations in the ice from the present to the late Wisconsin glacial period. The data points in the upper portion of the curve represent time periods of from 25 years to 50 years. The step curve in the lower portion of the curve represents a continuous sequence of measured samples, each extending over approximately 100 years. A 940-year climatic period is suggested, which is indicated by the arrows in the upper curve and the maximum peaks in the lower curve.

1969 Results

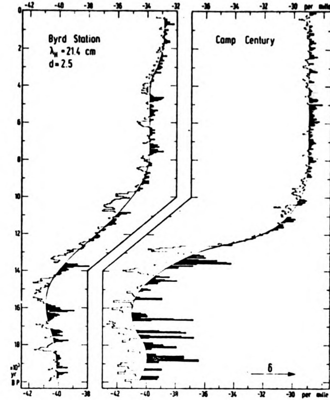


Fig. 6 The Byrd Station and Camp Century δ records measured in 50 yr sequences during the past 20,000 yr (according to the time scales used in Fig. 5c and e). The δ values exceeding the smoothed curves are set off in black. Relative to the Camp Century record, the Byrd Station shows less variation in the Wisconsin glaciation and a smaller shift in the transition period. Also note the difference in the post-glacial period.

1971 Results

Figure 11. A comparison of results from O^{18} analysis from 1969 and 1971. Reprinted with permission from Dansgaard et al., 1969 and Johnson et al., 1971. Copyright (1969) American Association for the Advancement of Science.

for the period of interest, the temperature pattern indicated in the 1971 profile differs from the pattern in the 1969 profile. The 1969 profile shows a clear trend toward colder temperatures between approximately 2500-2100 B.P., followed by an equally clear trend toward warmer temperatures beginning just prior to 2000 B.P. and lasting to about 1600 B.P. The 1972 profile, with many more data points, shows predominantly colder temperatures from approximately 2600-2300 B.P., followed by predominantly warmer temperatures from approximately 2300-1700 B.P.; between approximately 1700-1500 B.P., there is no predominant trend. Thus, while helpful to some degree, the data from the Greenland Ice Core has not yielded the definitive solution to problems of climatic change which some researchers had hoped it would provide.

Evidence from ocean cores. Unlike ice cores, ocean cores have long been used as keys to past environments. They have not proven particularly useful in this survey of information on climatic change, however, because they rarely provide data on periods as recent as that of interest (for example, see Sancetta, Imbrie, and Kipp, 1973). Often the upper layers of sediment are disturbed, either by the actual coring procedure or by natural processes, and are not reliable. If the sedimentation rate is too low, the definition of the core samples will be so broad that changes of the magnitude of interest are not evident. Even if the sedimentation rate is higher, the high cost of analysis and/or the purpose of the investigation may dictate that the cores be sampled at too broad an interval to reveal changes of the type sought.

Despite these problems, at least one recent paper has dealt with core data from the period of interest. Wiseman (1966) has studied a core from an area of rapid sedimentation in the equatorial Atlantic.

Taking care to avoid the pitfalls of his method, which depends on carbonate sedimentation rates, Wiseman finds that a cooler phase occurs with a mid-point about 2050 B.P. He correlates this phase with the major Iron Age flooding in Britain as well as some other climatically significant events of that time. However, his results provide no information on the climatic character of the crucial period which follows.

Evidence from Paleobotanical sources. Paleobotanical evidence for climatic change comes from a variety of sources. Three of them will be discussed here: peat, pollen and radiocarbon dated podzolic paleosols. Because information on peat growth and pollen is usually gathered together, these two kinds of data will be considered together. Information from paleosols will be considered separately. Before considering the evidence from peat and pollen, it is important to recognize some of the limitations of these data.

The type of peat discussed here is ombrogenous peat, that is "its genesis and continued growth depend on a balance of precipitation over evaporation; it does not primarily owe its origin to very favourable and localized topographic situations (e.g. basins) (Nichols, 1969a:61)." Peat is a useful material for detecting climatic change because its occurrence is widespread, its growth is closely controlled by climatic conditions, it is accurately datable by radiocarbon techniques, and it provides a good matrix for the preservations of pollen and plant macrofossils.

In the past, layers in which peat growth has stopped and then begun again (called recurrence surfaces) have been used as climatic indicators. Recurrence surfaces were given alphanumeric names and were originally thought to indicate the boundaries of broadly synchronous climatic periods in Europe. These periods, as described in the Blytt-Sernander system (Feunder, 1952; Bryson and Wendland, 1967) served as important tools in the deciphering of climatic changes in Europe. However, with further research, and the advent of radiocarbon dating, it was found that recurrence surfaces were not consistent from place to place (Godwin, 1960, 1966). Many palynologists still believe that the growth of peat holds important information on climatic change and some still use recurrence surfaces as markers, especially the RYIII or "Grenzhorizont", which dates the beginning of the sub-Atlantic period. But, as Godwin has pointed out, until more is known about the ecology of peat growth, recurrence surfaces will have to be regarded with circumspection as indicators of climatic change.

Nevertheless, the nomenclature of the Blytt-Sernander system of climatic episodes, minus its European vegetational associations, including recurrence surfaces, has proven at least potentially useful in describing climatic changes in North America. An updated version of the system has been presented by Bryson, Baerreis, and Wendland (1971) and is illustrated in Table 3. As an alternative to recurrence surfaces, Nichols (1968) has found that in the Arctic, the researcher can date the interface between peat and inorganic layers as an indicator of climatic change.

A second source of paleobotanical information on climate is the analysis of fossil pollen. Pollen analysis, when coupled with radiocarbon dating, is perhaps one of the most accurate and powerful of the tools currently available for discovering the nature of climatic history. When pollen analysis is used in the arctic and many parts of the

subarctic, an additional advantage accrues because human influence on the environment in terms of alterations in the flora are minimal. Therefore, trends which might be disturbed or masked elsewhere can be observed clearly in the arctic (Frenzel, 1966; Nichols, 1972).

Table 3. Up-dated version of Blytt-Sernander system adapted to North America by Bryson et al., 1971. Reprinted with permission. Copyright, 1971. University Press of Kansas.

Episode	Tentative date BP	Subepisode division dates	
(Late Glacial)*			
	ca. 10,500		
Pre-Boreal			
	9650		
Boreal		9140	
	8450		
Atlantic		7730	5980
	4680		
Sub-Boreal		3970	3480
	2890		
Sub-Atlantic			
	1690		
(later episodes or subepisodes)**		760	

*Glacial chronology and terminology is not considered here.

**A nomenclature of post-Sub-Atlantic time has been suggested elsewhere by Baerreis and Bryson (1965).

To use pollen analysis accurately, it is important that the researcher understand the factors affecting the modern "pollen rain" in the area under study (Fredskild, 1961; Ritchie and Lichti-Federovich, 1967; Tauber, 1967), because the pollen rain does not correspond with the vegetation. Along with the modern pollen rain, it is important for the researcher to anticipate the effects of "fall out" or pollen carried in from distant areas. Such pollen can provide important clues to the nature of the prevailing winds and weather patterns, and on the movement of vegetational zones in the past (Nichols, 1970; Terasmae, 1967).

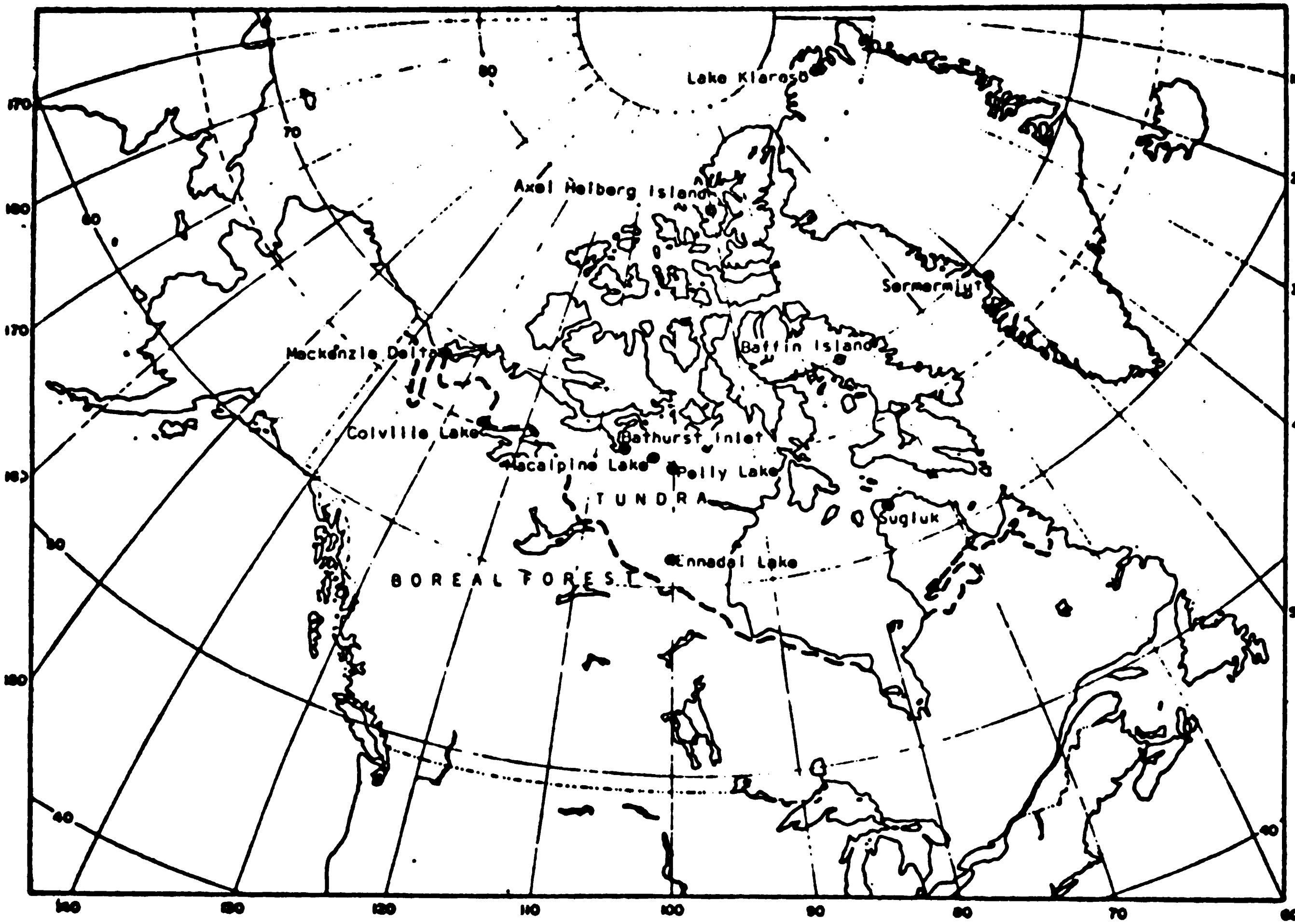


Figure 12. Map of northern areas from which paleobotanical evidence is discussed. Broken lines indicate northern forest limit. Reprinted with permission from Nichols, 1972.

Finally the researcher must also recognize the essentially statistical nature of the techniques used in pollen analysis and make interpretations accordingly.

The best summary of peat and pollen evidence relevant to climatic change in the eastern arctic has been done by Nichols (1972). Drawing on his own extensive work in the Canadian arctic and subarctic, on the work of other researchers in that area, and on the findings of the Danish palynologist, Bent Fredskild (who has sampled a number of areas in Greenland), Nichols' summary is broad ranging and thorough (Figure 12 shows the locations discussed). He suggests that a gradual cooling period began between 3500-3400 B.P. in northern Canada, 3300 B.P. in Peary Land northern Greenland, and sometime after 3000 B.P. on Axel Heiberg Island. Cooling continued until about 2500-2200 B.P. either as a regular decline (as, for example, at Pelly Lake, (Nichols, 1970)) or in steps with occasional temporary improvements (as seems to be the case at Ennadai Lake (Nichols, 1967a&b)).

This cooling trend was followed by a severely cold climatic episode which reached its maximum about 2100 B.P. As a result of this severe climatic period, the northern edge of the boreal forest or "treeline" moved southward and the area encompassed by tundra sharply increased. The timing of this event was broadly synchronous, although severe climatic conditions persisted longer at some sites probably due to their geographic location. By 2000 B.P., recovery from this severe cooling had begun (Nichols, 1970; Fredskild, 1969). However, the warming trend did not really register in terms of vegetational changes at some sites until slightly later (1800 B.P. at Colville Lake, 1600 B.P. at Sugluk, and 1500 B.P. at Ennadai Lake).

The evidence for this summary comes from seven different locations in the central and eastern Canadian arctic and subarctic, and it is valuable to examine each of these locations more closely because the findings from each one vary. Starting in the west, the first site is at Colville Lake in the Anderson River drainage southeast of the MacKenzie River delta. Cooler, wetter summers, evidenced by an increased number of Sphagnum bog moss spores and less oxidized Sphagnum peat, began to occur between 4130± 55 B.P. (WIS-294) and 3180± 65 B.P. (WIS-314). Shortly after 3180± 65 B.P., Sphagnum spores almost disappear from the record, the peat stops growing, and Picea (spruce) pollen percentages fall. The forest-tundra ecotone retreated southward across Colville Lake and the area was increasingly exposed to the cold, dry Arctic tundra summers. This severe episode lasted until approximately 1810± 60 B.P.(WIS-297) when slow growth of a heath peat began. Picea percentages have not increased again, and a generally cool, dry summer climate persists. Nichols' findings concerning the onset of cooler conditions and the timing of the permanent southward movement of treeline are in general agreement with the work of Ritchie (1972) in the MacKenzie River delta.

Somewhat further east along the arctic coast at Bathurst Inlet, Terasmae (1965) found that at 2170± 140 B.P. (GSC-138) Picea pollen percentages reached a minimum and Pinus pollen completely disappeared. After this date, the percentage of both of these genera increased to a maximum considerably after 1850± 140 B.P. (GSC-137). In this case, both spruce and pine pollen are considered "fall out", that is pollen blown into the area from the northern forest boundary further south. When treeline withdraws southward in response to deteriorating climatic conditions, the amount of pollen from forest species found in sites north of the treeline decreases. Correspondingly, when the percentage of these pollens increases, a northward movement of treeline is generally indicated.

Still further east at Pelly Lake on the Keewatin-MacKenzie border, changes in the percentages of windblown spruce and pine pollen also provide the major evidence for climatic change. Here percentages of Picea and Pinus pollen began to decrease about 3360± 70 B.P. (WIS-216), suggesting the retreat southward of treeline. Cooler summers continued until minima for these two species were reached at about 2080± 60 B.P. (WIS-292), indicating summers were at their coldest and the maximum southward retreat of the forest edge had been reached (Nichols, 1970).

A fourth location, MacAlpine Lake, is within 100 km. of Pelly Lake. It is the only location which does not conform to the pattern outlined by Nichols (Terasmae, 1967). Terasmae's analysis of the pollen from a peat sample overlying inorganic sediment showed no notable change in the pollen curves for either Picea or Pinus. On this basis, Terasmae suggests that there was no change in the climatic factors influencing the dispersal of these pollens during the past 2000 years. However, no other data from the area, including Pelly Lake, supports this finding. Nichols (1970, 1972) proposes one explanation for the conflict by pointing out that only one radiocarbon date was taken. Because there is only one date, 2330-150 B.P. (GSC-300), which came from the base of the sample, there is no clear indication of how long peat growth continued. If peat growth ceased after only a few centuries, little or no change would be recorded. Only additional radiocarbon dates and pollen samples will solve the problem.

At Ennadai Lake, further south and slightly east in Keewatin, irregularities in the percentages of spruce pollen, variation in the percentages of *Sphagnum* spores, and changes in the degree of peat humification seem to mark a period of fluctuating climatic conditions from 3500-2600 B.P. After 2600 B.P., there are indications of increased cooling. That is, pollen percentages for heaths increase, spruce percentages remain irregular, *Sphagnum* spore counts drop quite low, and the peat is humified, indicating slow growth in a cold, dry, oxidizing environment. The peat also contains sand grains which probably indicate the partial breakdown of local plant cover. Some recovery from this severely cold period can be seen in the pollen diagrams by about 1500 B.P.

Still further east at Sugluk on northern Ungava, Bartley and Matthews (1969) have taken a number of peat sections from the tundra. These consisted of thin peaty layers separated by thick horizons of marine sands. High percentages of pine and spruce pollen (again fall out), representing a mild summer climate, have been dated 2840± 160 B.P. (GSC-818). Molluscs from the marine sediments also seem to indicate warmer seas than at present. This mild episode was followed by colder and drier conditions in which at one site, windblown sand was deposited presumably due to the breakdown of the plant cover and subsequent wind erosion. The colder spisode seems to have lasted until about 1600 B.P. when there was a marked onset of *Sphagnum* peat growth indicating warmer, moister conditions. In another pollen diagram from Sugluk, Terasmae *et al.*, (1966) found a similar pattern in which peat overlies sand. The peat has a basal date of 1625± 175 (I-727), which would tend to confirm Bartley and Matthews' findings. However, in dealing with their data Bartley and Matthews, at least, have some difficulty separating local effects of changing relief and substrate from the more general effects of climatic change. Such difficulties throw some doubt on the validity of these results.

The seventh and final location used in Nichols summary is Axel Heiberg Island (Hegg, 1963). Between 4000-3000 B.P., this area had a climate more favorable for plant growth than the climate of today. Sometime after 3000 B.P., dessication occurred. Hegg explains that this may be due to geomorphological changes, but Nichols suggests it may also be due to a shift to a colder, drier climate. Hegg did not count and record pollen which might have been transported long distances; hence the type of information obtained from other sites above treeline is not available.

In addition to the data from the central and eastern arctic and subarctic presented by Nichols, considerable palynological work has been conducted in Labrador. This data has been summarized well by Fitzhugh (1972, 1973), and seems to indicate that cooler conditions stimulated a decline in the boreal forest which lasted from approximately 3500 B.P. to 2000 B.P. After this date, ameliorating conditions brought about a readvance in the forest-tundra border. This data would seem to agree, at least in part, with Nichols' summary.

A second source of confirmation for Nichols' conclusions comes from his own work in southern Manitoba (Nichols, 1969). At Porcupine Mountain, he found a cooling trend marked by the transition from grassland to predominantly spruce forest about 4200 B.P. Cooling continued and reached a culmination between 2450 and 2000 B.P. when very rapid

Sphagnum peat growth took place and sporogenesis increased. At Lynn Lake and Root Lake, Sphagnum spores increased at 2170 B.P. and 2380 B.P. respectively (Nichols, 1967c). A decline in spruce and pine pollen percentages accompanies the Sphagnum increase at Lynn Lake suggesting that these changes have a climatic cause. At Riding Mountain, also in southern Manitoba, Ritchie (1969) found that the formerly existing grasslands were replaced by boreal forest which was moving southward at about 2500 B.P., presumably in response to a cooler and/or wetter climatic episode.

The best confirmation outside of North America for the general climatic sequence contained in Nichols' summary comes from the work of Fredskild (1967, 1969, 1972, 1973) at Sermermuit near Jacobshaven, Disko Bay, Greenland. About 2650-2550 B.P., this area experienced an alteration in moisture conditions causing the preexisting willow scrub to be replaced by a Sphagnum bog. Fredskild lists the possible causes of this change as: a) higher precipitation in the form of rain during the summer, b) a heavier snowfall during autumn and winter, or c) a rising permafrost level. Fredskild sees this event as agreeing with both the occurrence of RYIII, the regrowth of peat on raised bogs in northwestern Europe and Einarsson's (1969) data from Iceland which shows that climatic deterioration set in between 2650-2450 B.P. Flooding horizons and the closing of Alpine passes by ice (Godwin, 1956) are among the other confirming evidence of widespread climatic deterioration at this time in northern Europe.

After this humid period, a short dry period in which a grass heath predominates set in. However, by 2250-2150 B.P., a short moist period again appeared, although this period was not as pronounced as the earlier one. By 1950 B.P. or shortly thereafter when the Dorset people settled at Sermermuit, the area was covered by a rather dry dwarf-shrub heath, indicating the return of warmer dryer conditions.

Evidence from other parts of Greenland in which Fredskild has done research has also confirmed the basic outline sketched so far. In Northern Greenland, climatic deterioration began about 3200 B.P. Sometime after 2700 B.P., the Peary Land fjords were closed permanently by ice. By 2100 B.P., the cold and aridity reached their modern desertic levels, and there appears to have been little change since. In the bogs of southern and western Greenland, the moist conditions also noted at Sermermuit indicated for the period beginning 2650-2450 B.P.

The third source of paleobotanical information comes from the detection and dating of paleopodzols. Paleopodzols are fossil soils, usually formed when the vegetational cover is primarily coniferous forest. These soils frequently contain plant macrofossils and/or pieces of charcoal from forest fires, which play an important part in subarctic boreal forest eolology (Nichols, 1967b). Paleopodzol studies are useful for detecting periods in the past when the northern edge of the boreal forest changed its location. During warmer periods, treeline moved north of its present location; during colder periods, it moved southward sometimes attaining a position considerably south of its current location. The onset of colder periods can be readily detected from such data, for when climatic deteriorations set in, the forest becomes dessicated and more easily destroyed by lightening-ignited fires. The recession of treeline, therefore, takes place quite rapidly and is often marked by datable charcoal in the soil. Considerably less is known about how much time is required for restoration of the forest during warmer periods, so that this method is somewhat less useful for dating the onset of warming trends.

The Arctic front (Figure 13) has an unusual relationship to the occurrence of paleopodzols in the subarctic north of treeline. Bryson (1966) has put forward the hypothesis that since climate is the ultimate ecological control, it is possible to delineate major biotic regions which coincide with the modal position of distinct airmass boundaries (fronts) and which are occupied by a known mean annual sequence of airmasses (Bryson and Wendland, 1967). The arctic front is the boundary between airmasses which originate in the arctic and more southerly airmasses originating in the Pacific area, in the Gulf of Mexico, and in the Atlantic. From an analysis of airmasses and streamlines, Bryson (1966) has established that the mean summer position of the arctic frontal zone coincides quite closely with the northern boundary of the boreal forest zone, while the mean winter position of the arctic frontal zone coincides fairly closely with the southern boreal forest boundary.

On this basis, Bryson has concluded that the boreal forest zone in North America corresponds to the zone over which the arctic front oscillates (in the mean) during the year. Bryson *et al.* (1965), Sorenson *et al.* (1971), and Sorenson and Knox (1972) have demonstrated that the northern forest limit has advanced northward during periods which, on the basis of other evidence, are considered warmer than normal. Andreev (Hare, 1968; Tikomirov, 1966) has demonstrated similar post-glacial movement of the arctic treeline in the Soviet Union, and Lamb (1966) has suggested similar zonal shifts have accompanied climatic changes in Europe.

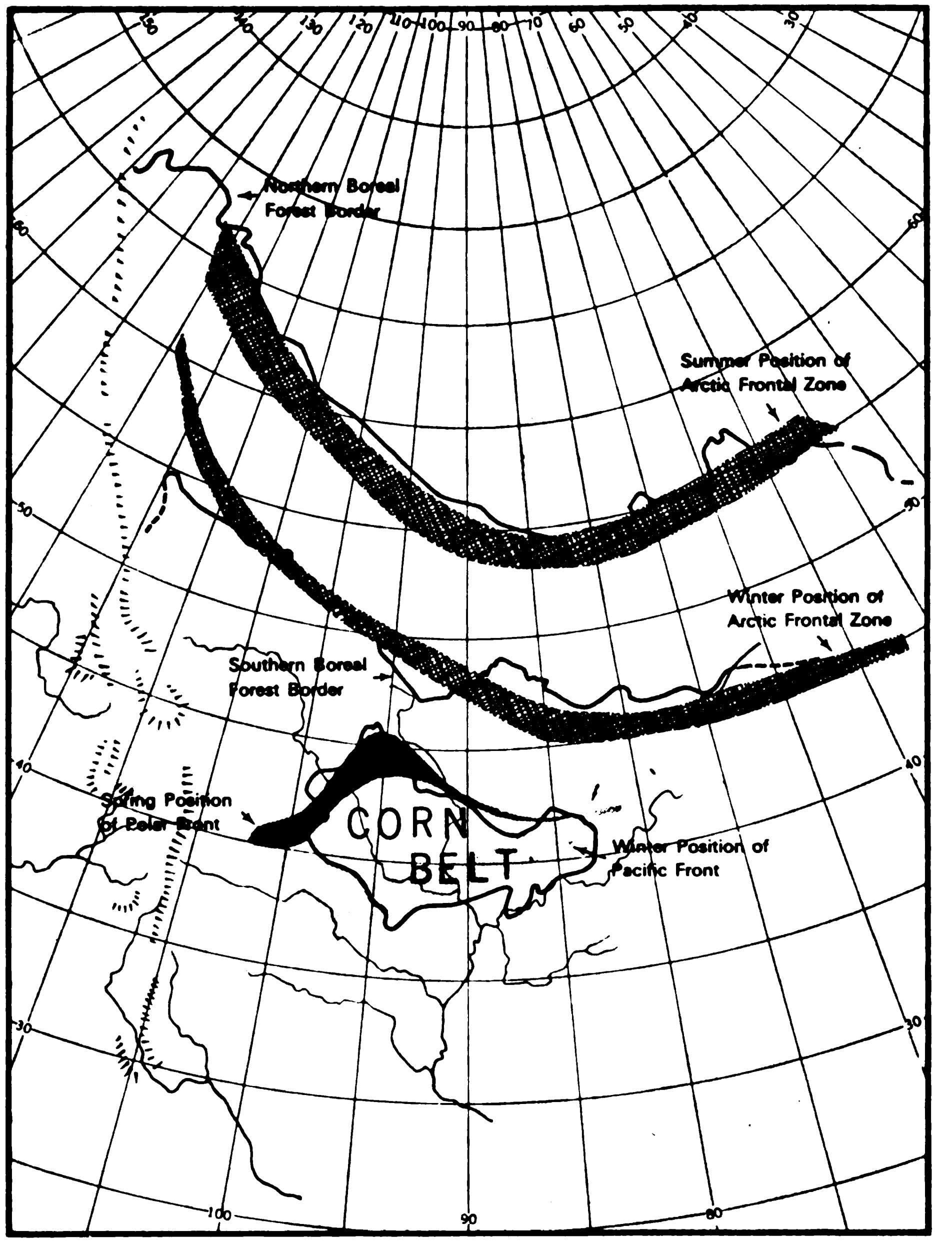


Figure 68. The coincidence of the "corn belt" and "boreal forest" biotic regions with meteorologically defined climatic (air mass) regions. Climatic regions are taken from Bryson (1966), Fig. 32: "corn belt" from "soils of the North Central Region of the United States" (1960): and the boreal forest generalized somewhat from Rowe (1959) and Larsen (1967).

Figure 13. Map showing coincidence of the Arctic Front and the Boreal Forest Zone. Reprinted with permission from Bryson and Wendland, 1967.

Bryson's conclusions have led him to suggest that the forest vegetation responds to a characteristic assemblage of climatic values best defined by the concept "airmass". However, in proposing an alternative relationship, Hare (1968:458) has suggested that the arctic front may "lie in its chosen position because of differences in albedo, evaporating potential, and aerodynamic roughness between the tundra and the forest...". Thus, instead of viewing the biotic limits as caused by the circulation patterns, Hare would be inclined to view both biotic limits and circulation patterns as effects of over-riding circulation controls. Whether one accepts Bryson's or Hare's explanation, the evidence of past movement of treeline seems to be a good indicator of climatic change in northern North America.

In 1965, Bryson et al. demonstrated that podzolic paleosols or paleopodzols occurred as much as 280 km. north of the present forest border. Since the formation of a podzol is a process generally associated with the presence of coniferous forest, Bryson and his colleagues interpreted their findings as an indication of a more northerly position of the boreal forest in the past. By dating these soils (using radiocarbon methods), they determined that treeline has advanced to a position considerably north of its present one at least twice in the past 4000 years.

Using similar techniques, Sorenson et al. (1971) and Sorenson and Knox (1972, 1974) have attempted to broaden and refine the temporal and geographic scope of these findings. In the vicinity of Ennadai Lake, it appears that the forest border advanced northward about 2900 B.P. following a retreat south of its present position. This northward movement continued for about 50 km. beyond the present location to the north end of Ennadai Lake, where it seems to have become stationary by about 2670± 105 B.P. (WIS-93). It fluctuated southward between approximately 2200 and 1800 B.P. and then again began a northward advance. These results correlate to a reasonable degree with Nichols' findings based on the pollen and peat growth evidence from Ennadai Lake.

Evidence of temperature changes. Although temperature is not the only factor involved in the climatic changes which have been discussed, it is helpful to obtain some grasp of the effect of these changes by examining the temperature change estimates made by various investigators. In studying glacial activity in southeastern Alaska and the Yukon Territories, Goldthwait (1966) estimates that a drop of 2°C would bring about the widespread glacial advances he recorded. Similarly, in his discussion of the general agreement between glacial and palynological data from northwestern North America and parts of the southern hemisphere, Huesser (1966) estimated that temperatures cooled 2-3°C at the onset of the Sub-Atlantic period.

More recent estimates by Denton and Karlen (1973) have led them to propose that the drop in temperature in the mountains of Swedish Lapland at the onset of glacial conditions was probably no more than 1°C. At the same time, they felt that the overall maximum variation during the Neoglacial period was no more than 3.5°C. Their estimates were based in part on mass budget studies performed by Schytt (1967), and his estimates of how much temperature change would be required to raise or lower the snow equilibrium line by the amount required to bring about the appropriate change in glacial conditions.

Denton and Karlen's estimate coincides very closely with the estimates which Nichols (1968) has provided based on his palynological data from northern Canada. Nichols' diagram of temperature change (Figure 14), which draws on evidence of treeline movement, does show question marks for some periods in which his data is scanty. However, he envisages post-3000 B.P. temperatures as decreasing less than $1^{o}C$ and increasing no more than $2.5^{o}C$. Thus, it would appear that temperature variations of no more than $3.5^{o}C$ are involved in the climatic change under discussion.

While experts such as Bryson (1974) have described the impact which minor temperature changes can have, the 1974 growing season in central North America provided even the casual observer with a striking example. Despite the lack of agriculture, slight temperature changes have a definite impact on the food resources of arctic people. The nature of this impact will be examined at some length in succeeding portions of the chapter.

Evidence from climatic models. One final form of information pertaining to climatic change is climatic models such as were considered briefly in the discussion of causes of Baffin Island glaciation. Climatic models have been considered last because they are based on parameters inferred from all the various kinds of evidence examined thus far. These parameters are translated into meteorological variables which can be manipulated by computer according to various atmospheric models. Such models are particularly valuable because they provide detailed insight into the meteorological processes which may have produced the climatic conditions of the past. The models can also serve as a partial check on the consistency of the data used in their construction. The major disadvantage of climatic models is that much of the information they produce is highly technical and therefore often

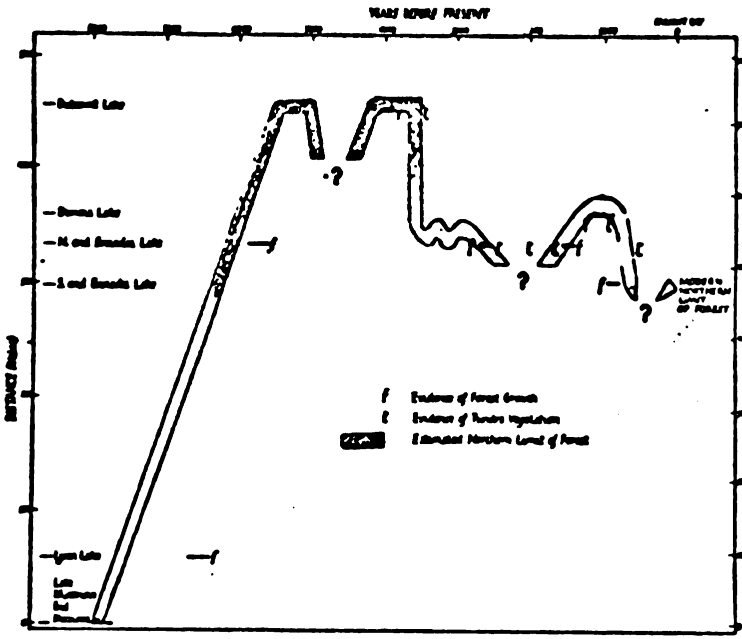


Fig. 7. A tentative reconstruction of the location of the northern limit of continuous forest along the meridian 100°W in central Canada. Stratigraphic evidence for forest (f) or tundra (t) is shown by short horizontal lines which represent the radiocarbon date and the standard deviation. The rest of the diagram is based on the radiocarbon-date pollen diagrams from the north end of Ennadai Lake and from Lynn Lake, and this palynological and stratigraphic evidence is less unequivocal. For instance, the vegetation changes following 5,000 B.P. are derived from radiocarbon-dated palynological evidence, but there is no clear stratigraphic evidence of a change from forest to tundra, so that the magnitude of the ecotonal movements can only be inferred. It is not known how far south of Ennadai the forest retreated between 2,500 and 1,500 B.P. and after 600 B.P.

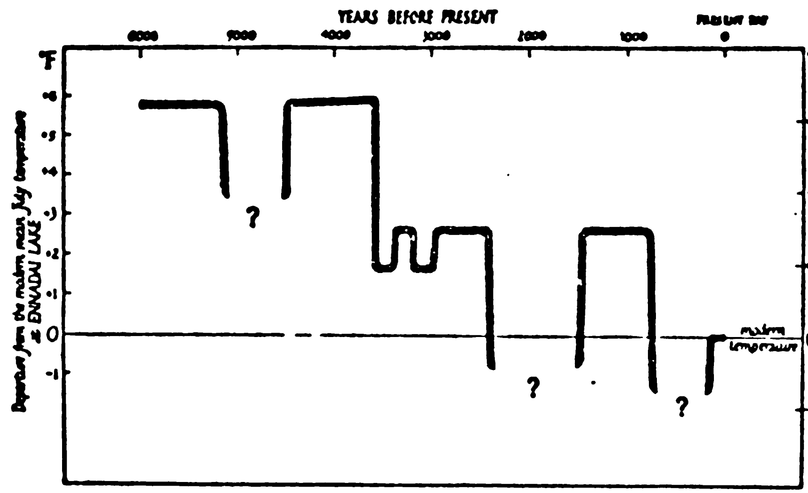


Fig. 8. Estimated changes in the mean July temperatures at Ennadai Lake, Keewatin, derived from Figure 7. The departures from the modern means were calculated from the distance of the forest limit from Ennadai. When, for example, the forest extended 200 km north of Ennadai Lake, it was assumed that the temperature at Ennadai resembled that now found 200 km to the south of that site. The probable error is ±0.5°C. The climatic date were from post-1945 observations covering less than a decade. The magnitude of the cooling after 5,000 B.P. is not known, beyond the fact that temperatures were not as low as modern figures. The deterioration from 2,500 to 1,500 B.P., and following 600 B.P., witnessed summer temperatures below modern values, but the amount of cooling is unknown.

Figure 14. Treeline fluctuations based on data from Ennadai Lake and temperature fluctuations which have been inferred from the treeline data. Reprinted with permission from Nichols, 1968.

difficult for the nonspecialist to utilize effectively.

One prominent researcher in the field, H.H. Lamb, who with his colleagues (Lamb, 1963, 1964, 1966, 1972; Lamb et al., 1966), has shown that the Sub-Atlantic cold period began in northern Europe about 2450 B.P. This period was apparently characterized by cool, wet summers and relatively mild winters. During this period the models indicate heavy storm activity for both winter and summer months in some parts of Europe, particularly Scandinavia. The resulting heavy precipitation was favorable for the growth of glaciers, despite the relatively mild winters at lower elevations (Lamb, 1972). Following this colder episode, Lamb finds a warmer period which reached a maximum about 1650-1550 B.P., but gives no definite date of the onset of this period.

SUMMARY OF BROAD CLIMATIC PATTERNS

In this part of Chapter 4, numerous studies pertaining to climatic change in the eastern arctic from 2500 B.P. to 1500 B.P. have been discussed. Some of these data are not definitive and some are contradictory. Overall, however, there is enough accurate and consistent information available so that sound, reasonable conclusions may be drawn to provide a firm basis for the questions at hand. The useful data comes from a wide variety of sources and a broad range of geographic areas. It falls into three categories. First, evidence which indicates that warmer, dryer conditions were present by at least 1900 B.P. Second, evidence which can be interpreted as generally supporting a 1900 B.P. date, but which does not specifically pinpoint that date. And third, the evidence which indicates that warmer conditions were not present until around 1600 B.P. or later.

Strong support for the 1900 B.P. date (the first category) comes from sources such as Porter and Denton's (1967) summary of North American neoglacial activity, Fitzhugh's (1972) summary of pollen data from Labrador, Fredskild's (1967, 1969, 1972) summary of pollen data from Greenland, Nichols' (1970) pollen evidence from Pelly Lake, Terasmae et al.'s (1966) pollen evidence from Bathurst Inlet, and a variety of sources on glacial activity, pollen analysis, and peat growth in Europe. McGhee's inferences based on cultural change in the eastern arctic also fit here.

Evidence which is generally supportive, but does not permit the pinpointing of a 1900 B.P. date (the second category) comes from Denton and Karlen's (1973) glacial summary, from Lamb's climatic modeling research, and from the Greenland Ice Core data (Dansgaard et al., 1971). If the INSTAAR climatic model for northern Baffin Island is correct, Andrews' (1970) and Miller's (1973) data on glacial advances of the Barnes Ice Cap and the Cumberland Peninsula, as well as Weidick's (1968) and Ten Brink's (1971, 1972) accounts of glacial movement on the west coast of Greenland also can be placed in this category.

Data which clearly contradict a 1900 B.P. date (the third category) are not nearly so strong. Such data come from a narrower range of sources and are geographically limited to northern North America, south of the Arctic islands. Among this contradictory data are the results of Goldthwait's (1966) glaciological work in southeastern Alaska and the Yukon Territories, where he found that widespread glacial activity continued until 1600 B.P. However, several nonglacial factors such as topography affect glacial activity in this area and cause a wide range of response times in the glaciers. Such effects may be responsible for Goldthwait's results. Other contradictory glaciological evidence comes from Benedict's work in the Front Range, but more dates are needed to bracket Neoglacial activity in this area before this contradiction can be evaluated or resolved.

Contradictory paleobotanical evidence comes from two areas. The first is from Sugluk where the onset of the warm period is dated at 1600 B.P. The basis for this date is the juxtaposition of a radiocarbon dated peat layer with basal inorganic sediments (Bartley and Matthews, 1966; Terasmae et al., 1966). From this juxtaposition, it is inferred that a dryer, colder period had preceded the warmer, wetter period indicated by peat growth, with the onset of peat growth taken as the date for the beginning of the warm episode. However, Bartley and Matthews express some doubts about their ability to separate local topographic disturbances from those caused by long-term climatic changes. Such doubts raise some question about these results. The second source of contradictory paleobotanical data is from the vicinity of Colville Lake (Nichols, 1972) and Ennadai Lake (Nichols, 1967a&b), two large inland lakes in the central Canadian subarctic. It is possible that some local geographic factor is operating in these areas which attenuates the effects of the warmer period.

Thus, on the basis of the evidence discussed in this part, it is reasonable to characterize the period from 2500-1900 B.P. in the eastern arctic as a cooler period while the episode from 1900-1500 B.P. or later could be described as one of warmer conditions.

PART 3

THE LOCALIZED EFFECTS OF CLIMATIC CHANGE

The preceding part provided evidence to support the broad outlines of climatic change during the period of interest. In order for such data to be useful to the archaeologist, however, it is necessary to show how these changes affected a given area, in this case the south coast of Baffin Island where the Nanook Site is located. It is not easy to bridge the gap in scale between the general conclusions about climatic changes and the specific climatic data needed for predicting how animal resources and human populations responded to those changes.

In an attempt to understand the effect of climatic change during an earlier period in the eastern arctic, Dekin put forward one possible way to bridge the gap. Called Vectors of Environmental Change, it is a general model of the climatic conditions expected during cooling and warming trends with implications for human populations. Figures 15 and 16, taken from Dekin's (1975) exposition of this model, present its basic elements; points underlying the various segments of the model are outlined below:

1. The dynamics of the earth's atmosphere may be seen as a large heat exchange system whose ultimate driving forces are extra-terrestrial in origin: (i.e., variations in the kind and amount of radiation reaching the earth).
2. Increased extraterrestrial radiation is associated with zonal circulation patterns characterized by predominantly east-west air mass movement, more stable and predictable weather

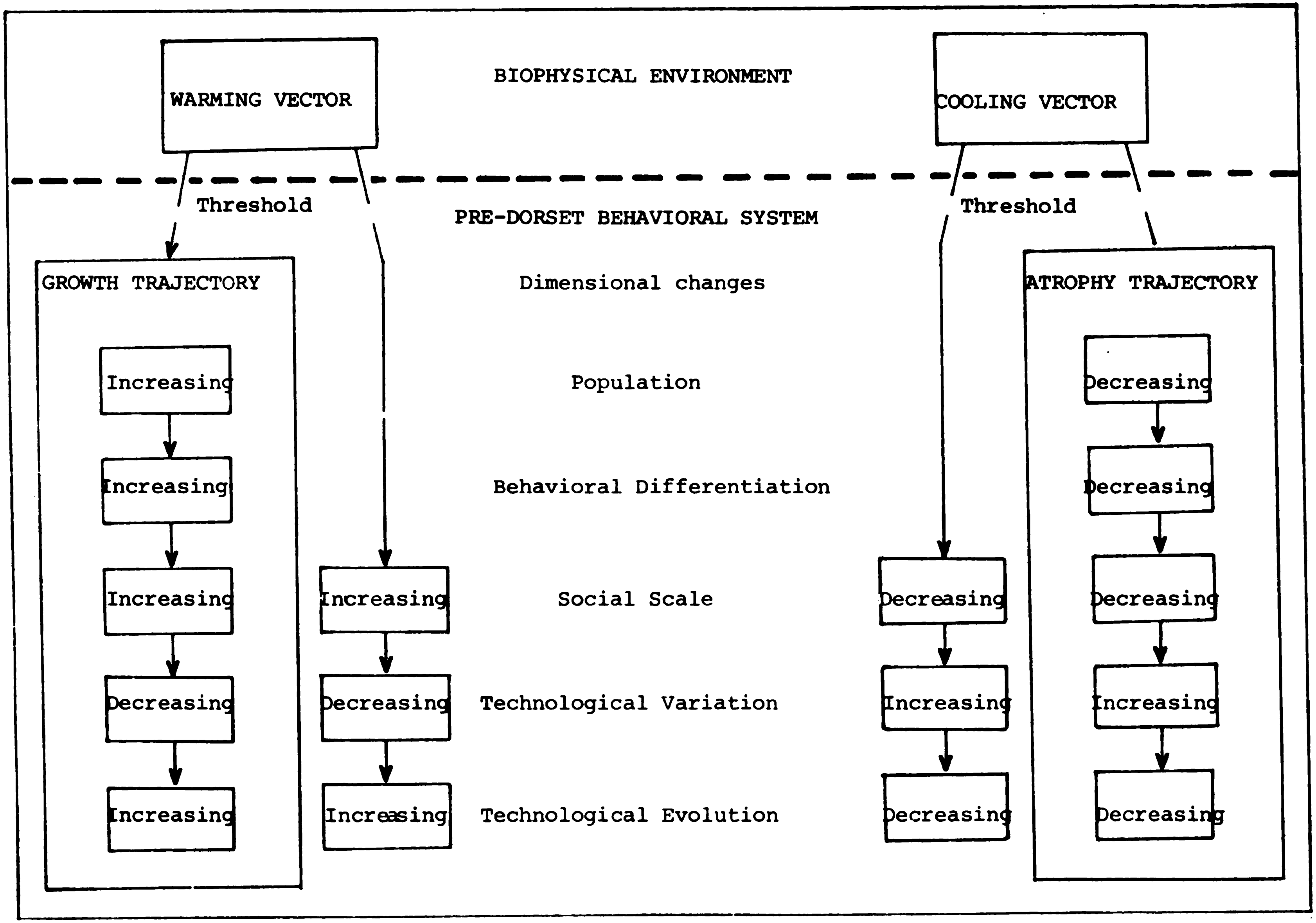


Figure 15: Dekin's Vector's of Environmental Change Model, Part 1.

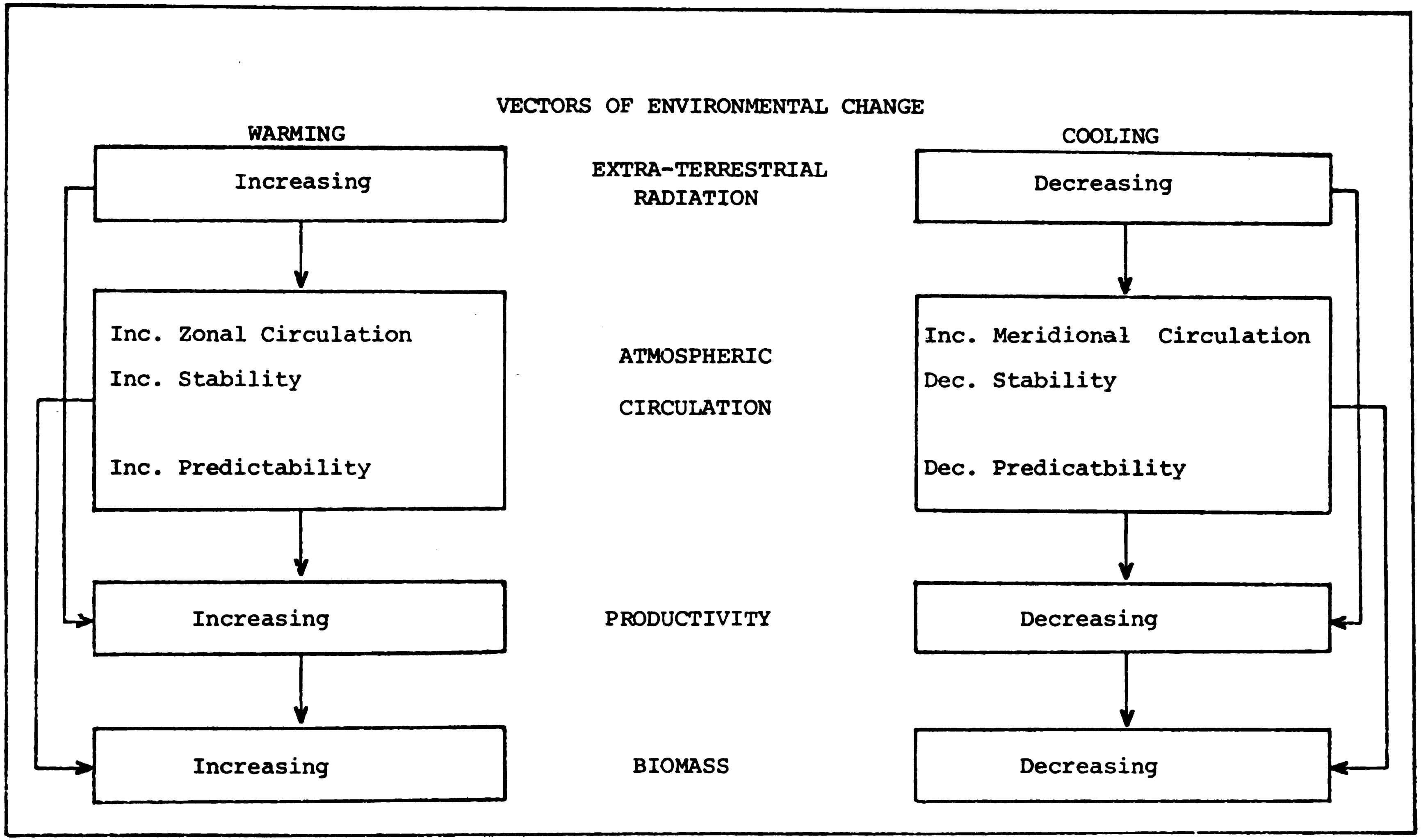


Figure 16. Dekin's Vectors of Environmental Change Model, Part 2.

conditions, and decreased exchange of air between arctic and temperate regions. Decreased extraterrestrial radiation is associated with meridional circulation patterns characterized by predominantly north-south air mass movement, less stable and predictable weather conditions, and increased exchange of air between regions due to fluctuating airmass interfaces.

3. Increased solar radiation results in an increase in the energy available to the ecosystem and thus an increase in productivity; decreased radiation means decreased productivity. Likewise, the increased stability and predictability in weather and climate should influence productivity positively, while the decreased stability and predictability should affect it negatively. Under unstable conditions, "marginal" communities are more likely to succumb.

4. Changes in productivity, predictability and stability are linked to changes in biomass with obvious implications for the human members of the food chain. Predictability, stability, and productivity cause biomass to increase; the opposite changes have the opposite effect.

Although Dekin goes on to link the changes brought about by his Vectors of Environmental Change to several aspects of the PreDorset Behavioral System, such links will not be given extensive consideration at this point; the concern here is primarily with weaknesses in the Vectors model which prevent it from bridging the gap. However, it is important to note that linkages between the Vectors of Environmental Change and their concomitant behavioral trajectories are mediated by thresholds of climatic change which must be exceeded, if the behavioral trajectory is to be activated.

To test the model, Dekin focuses on the archaeological evidence for the period following the marked environmental cooling trend around 3500-3600 B.P. Using data pertaining to 1) site frequency and size, 2) the variety of artifacts within sites, 3) the variety of artifacts among regions, and 4) artifactual change through time within each region, Dekin finds he can confirm only the minor cooling trajectory. Nevertheless, Dekin's model has two strengths. First, it attempts to take into consideration the dynamic nature of the processes involved; rather than stages, the model is formulated in terms of vectors and trajectories which are statements of tendency. Such formulations are certainly more appropriate for a diachronic study of the kind both Dekin and this author attempt than are the conventional stage-based models. Second, Dekin's model is highly explicit: The steps in the model and the reasoning behind them are clearly presented through graphs and descriptive discussion. Thus the model is not only clearly understandable, it is also available for discussion and comment by others.

The portion of Dekin's model which will be subjected to scrutiny in this section of the dissertation is the part pertaining to the Vectors of Environmental Change. Although this portion of the model could be helpful in bridging the gap between general conclusions about climatic change and specific climatic data pertinent to a particular area, three weak links prevent Dekin's model from filling this role.

First, many meteorologists and climatologists regard variation in extraterrestrial radiation, particularly solar radiation, as a poor basis for such a model. As Barry and Chorley (1971:280) point out, the present evidence for fluctuations in the solar constant is inconclusive. While clearly there is variation in solar activity, the processes by which variation in solar radiation affects the energy relationships within the earth-atmosphere system, thereby producing weather and climate, simply are not known (Barry and Perry, 1973:378; Flint, 1971:797). Although Flint and others are willing to grant the existence of such relationships, at least four climatologists in lectures or conversation (Frank Badgeley, Reid Bryson, Kenneth Hare, and Peter Webster, verbal communication) as well as Barry and Perry (1973:405-408) in print have noted that none of the numerous attempts to establish a statistical correlation between variation in solar radiation and climatic variation have been widely accepted in the scientific community. To prevent confusion, it is important to point out that both seasonal and multi-year differences in the radiation reaching a particular point of the earth do take place on account of changes in cloud cover, albedo, or other factors, but all these effects are generated internally by the earth-atmosphere system. As yet it has not been demonstrated satisfactorily that such variation is due to difference in energy input from extraterrestrial sources.

A second weakness prevents Dekin's model from bridging the gap between general conclusions about climatic change and specific climatic data pertinent to a particular area: even if the changes in solar radiation he postulates occurred, the kind of circulation pattern he links to the increases and decreases is contradicted by other investigators. Flint (1971:796), for example postulates that when the sun is more active, anticyclonic polar wind systems weaken and the circumpolar vortex contracts. Climatic belts are displaced poleward, the temperature gradient between pole and equator becomes gentler, and circulation becomes slower. All these situations imply a low index or a more meridional circulation pattern. Further verifying this pattern is the fact that under these conditions Flint anticipates increasing invasion of the high latitudes by warm, moist air leading to increased precipitation. Conversely, when solar activity diminishes, anticyclonic polar wind systems are intensified, middle latitude storm tracks tend to shift toward the equator, and the polar-equator temperature gradient is steepened. Under these conditions, colder temperatures and decreased precipitation would be anticipated in the higher latitudes. These events imply a high index or a more zonal circulation pattern.

While the link with variation in solar radiation which Flint postulates has already been disputed, Flint clearly contradicts the general pattern of association between warming and zonal circulation patterns and cooling and meridional patterns which Dekin posits. Various climatologists (Frank Badgeley, Roger Barry, and Peter Webster) have noted this contradiction in Dekin's model in conversation. Further, Dekin's linking of warming trends to greater weather stability and predictability and cooling trends to decreased predictability and stability is also questioned. While this issue is discussed at greater length below, it is a general observation by Barry (verbal communication) from recent Baffin Island climatic data, that at least for the winter months (September-May), colder periods tend to be more stable and less stormy. Such an observation makes sense because colder air is less capable of holding moisture; during a colder winter the point at which the mean air temperature becomes too cold to snow a significant amount is reached earlier in the winter.

A third weakness in Dekin's model is the assumption that a warming trend will bring about greater productivity among those animals of consequence to the human population of a given area. In fact, a warming trend can lead to a dimunition of the fast ice (Vibe, 1967) which would decrease, rather than increase, the local ringed seal population. Additionally, warmer conditions, especially if accompanied at key seasons of the year by increased precipitation, can produce highly unfavorable conditions for caribou (Pruitt, 1959a). Therefore, from the point of view of a human population, a warming trend may not necessarily lead to increasing productivity; conversely, a cooling trend may not always lead to decreasing productivity.

Because Dekin's model possesses significant weaknesses, an alternative model for bridging the gap between general conclusions about climatic change and specific climatic information for a given area must be found. In choosing an alternative model, the most useful guiding principle is that of uniformitarianism (Barry and Perry, 1973: 349). If an understanding of current processes affecting climatic change directs the choice, the most reasonable alternative to solar radiation as a basic mechanism for instigating change is a shift of the position of the standing waves persisting in the upper atmosphere and influencing gross weather patterns. Standing waves, sometimes referred to as Rossby Waves, are formed by major troughs and ridges in the upper air flow. The two major troughs, located at about 70° W and 150° E, are thought to exist as a result of the combined influence on upper air pressure and winds of large orographic barriers such as the

Rocky Mountains, and of heat sources such as warm ocean currents (in winter) or land masses (in summer) (Barry and Chorley, 1971:96).

Recent work by Namias (1969) has shown that changes in the temperature of the ocean's surface layer can affect the position and development of these waves, and that these changes can in turn have major effects over large areas of the northern hemisphere. In examining data from the Pacific Ocean, Namias found that the eastern North Pacific Ocean, after undergoing slow cooling which extended over vast areas and to great depths, experienced a number of processes by which this anomalously cold surface water was replaced by warm surface water. The presence of this large warm water body brought about strong, southwardly displaced cyclogenesis, or surface low pressure system formation, in turn producing a standing wave downstream. Further, the weather patterns generated by this warm water helped to perpetuate the warm water, thus extending and intensifying the pattern.

The result of this change was the abrupt creation of a new thermal regime for large areas of the northern hemisphere. The new circulation pattern resulted in significant climatic cooling, for example, over the eastern two-thirds of the United States (Namias, 1969). In higher latitudes, this amplification of the standing long wave pressure pattern over the northern hemisphere caused a significant lowering in the July freezing levels in several parts of the Arctic Archipelago (Bradley, 1973a), an increase in glacierization on parts of eastern Baffin Island (Bradley and Miller, 1972), and noticeable changes in temperature and precipitation (Bradley, 1973b).

Barry and Chorley's (1971:279) discussion of possible causes of climatic change lends additional credence to the notion of displacement of the standing waves. The first thirty years of the 20th century were part of a well-known warming trend; comparisons of pressure readings for 1900-1919 with those for 1920-1939 show that the Aleutian and Icelandic low pressure cells tended to move 5-10° of longitude eastward. Since the sector ahead of an upper trough is a very favorable location for a surface depression to form or deepen (Barry and Chorley, 1971:143), the longitudinal movement of the major standing waves could be inferred as well. Thus during a warming trend, there seems to be some eastward movement of the standing wave which normally lies at about 70° W over the eastern Canadian arctic; during cooling trends, there seems to be some westward movement of the standing wave.

Van Loon and Williams (1976) have taken the idea of a shift in the standing waves somewhat further. They have suggested that at least one recently observed variation in temperature, which has been interpreted as a global trend, instead may be primarily an artifact of sampling. Because most weather reporting stations are located on land, particularly in the higher latitudes which are more sensitive to change, and because stations are few and not well distributed over the area, weather data from large areas of the world, especially large areas of ocean prior to the advent of weather ships, are not regularly reported. Hence, when the standing waves shift, the mean temperature, precipitation, wind direction and so forth, which are recorded at the existing stations change, and synoptically, these changes are interpreted as climatic variation. However, if there were a large enough number of stations distributed to adequately sample the globe, the data from these stations might very well show that true global changes in climate have not taken place. This conclusion does not suggest that various land areas have not experienced changing climatic conditions; it suggests only that these changes may have global implications different from those previously considered.

One such previously unconsidered implication relates to other suggested causes of climatic change, and hence back to the first criticism of Dekin's Vectors of Environmental Change model. If shifts in the standing waves can be shown to be linked to changes in sea temperatures and ocean currents, there is little need to invoke causes such as increased air pollution or variation in volcanic activity as causes of at least short term temperature fluctuations. Similarly, as Namias points out:

> There seem to be no strong reasons why repetitive conditions such as those described cannot lead to climatic fluctuations of a much longer time scale than a decade. It may be short-sighted to invoke extraterrestrial or man-made activity to explain these fluctuations (Namias, 1970:743).

One note of caution should be observed with regard to the shift in standing waves hypothesis: it may not be the only factor operating. For most areas, data good enough to explore such shifts are available for less than one hundred years. Hence, climatic changes of the 30-50 year order of magnitude are the changes most clearly understood. When there is climatic change of longer duration, for example 100-500 years, some shift in the circumpolar vortex may also be involved (Brinkman and Barry, 1972; Barry, verbal communication). However, at present there simply is not enough information available to show whether expansions or contractions of the vortex are involved, and if so, what effects are due to such expansions and contractions and what effects are due to shifts in the standing waves.

The idea of shifting standing waves fits quite well with recent climatic evidence from Baffin Island (Bradley, 1973a&b; Bradley and Miller, 1972). This evidence was analyzed in order to help provide a better idea of what past climatic patterns in the area may have been like, and the analysis has contributed significantly to the hypothesis (discussed in the previous section) which attempts to explain why glaciation on Baffin Island is out of phase with the rest of the known Neoglacial sequence. The synoptic types developed by Barry (1974) and analyzed by Bradley (1973a&b) and his colleagues have served as the basis of much recent climatic evidence.

The majority of the observations used are taken from the period 1955-1972 or from some shorter period during that span. This period is interesting because from 1960 on, Baffin Island generally experienced increased mean annual temperatures along with what would generally be considered deteriorating climatic conditions. For that period, summers were somewhat cooler, and to some extent wetter. Winters, however, were noticeably warmer, with a marked increase in fall and early winter precipitation. These conditions resulted in falling summer freezing levels, increased glacierization, and more difficult coastal ice conditions (Dunbar, 1972). These conditions have proven relatively short lived (Andrews, verbal communication), but they provide some interesting analogs for periods of change in the past.

Since the occupation of the Nanook Site may have ended at the onset of a warming trend, those aspects of recent climatic patterns which are indicative of conditions during such a trend are of greatest interest. The analysis of synoptic types in terms of direction of airflow was particularly helpful in this respect. In looking at the summer months of June, July and August, Bradley (1973a) and his colleagues (Andrews et al., 1970) found that warm summer days were more frequently accompanied by westerly, particularly southwesterly, airflow; cool summer days showed a synoptic pattern of more frequent easterly, particularly northeasterly, air flow. From 1960-1970, most stations on Baffin Island showed a noticeable downward trend in mean summer temperature. Further, synoptic analysis showed a 29% decrease for the summer months in the frequency of days with westerly, particularly southwesterly, airflow patterns between 1961-1965 and 1966-1970. Finally, the period 1960-1970 showed a noticeable increase in winter temperatures and precipitation. While a synoptic classification catalog for all the winter months had not been completed in 1973, Bradley and Miller (1972) consider the warming observed during these months to be related to a higher frequency of days on which relatively warm, moist southerly air enters the region.

The paleobotanical record provides an exceedingly interesting confirmation of this analysis based on modern weather records. In examining data from seven pollen sites on the Cumberland Peninsula of Baffin Island, John Andrews (verbal communication) and Pat Webber found that warm and possibly wetter periods were marked by a patterned influx of exotic pollens. The first exotic species to show up in the profile is almost always Alnus, followed by Picea and others. This pattern matches very closely the order of appearance of exotic pollens in diagrams from the arctic and subarctic west of Hudson Bay in a southwesterly direction, and contrasts with the pattern found in sites east of Hudson Bay and in a south or southwesterly direction. Thus the influx of exotic pollens would seem to confirm a predominantly southwesterly airflow at least during the summer months of warmer periods.

Additional clues to the nature of climatic conditions resulting from a warming trend can be found in Bradley's (1973b) analysis of pressure surfaces for the area between 1955 and 1972. Figures 17 and 18 show the average height of the July 850 mbar surface for 1955-63 and 1964-72. These data show a displacement of the main center of the eastern Canadian trough north and west. During the former period, the area was dominated by a low pressure trough lying over Baffin Bay and southern Baffin Island. In the latter period (1964-72), the principal low pressure center occurred to the northwest, with the southeastern arctic dominated by a high pressure ridge. Pressure gradients across the archipelago were also much stronger during the latter period, indicating increased movement of air across the region, especially from the north (Bradley, 1973a:399).

These findings mesh well with those of Brinkman and Barry (1972; Barry and Perry, 1973:364) for Labrador-Ungava and Keewatin. Attempting to use extreme modern conditions as analogs for the past, they found that high winter precipitation over Labrador-Ungava was associated with a weaker than normal 700 mbar trough over eastern Canada, displaced to the west of its mean position. Southeasterly airflow components were very important under these conditions. Cool

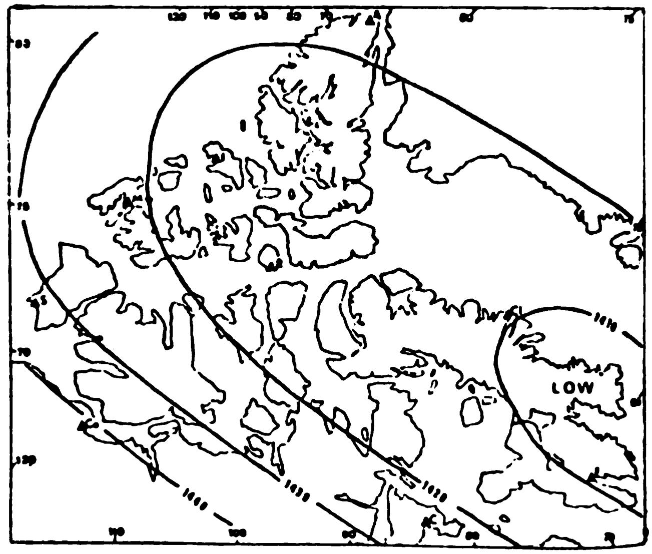


Fig. 1 Average height of the July 850 mbar surface, 1955-63, in geopotential metres (1 gpm ≃ 0.98 m). Letters refer to upper air stations mentioned in text. A=Alert; Cl=Clyde; C=Coral Harbour; Co=Coppermine; E=Eureka; F=Frobisher Bay; I=Isachsen; M=Mould Bay; R=Resolute; S=Sachs Harbour.

Figure 17. Synoptic pressure pattern typical of July during warmer summers. Reprinted with permission from Bradley, 1973.

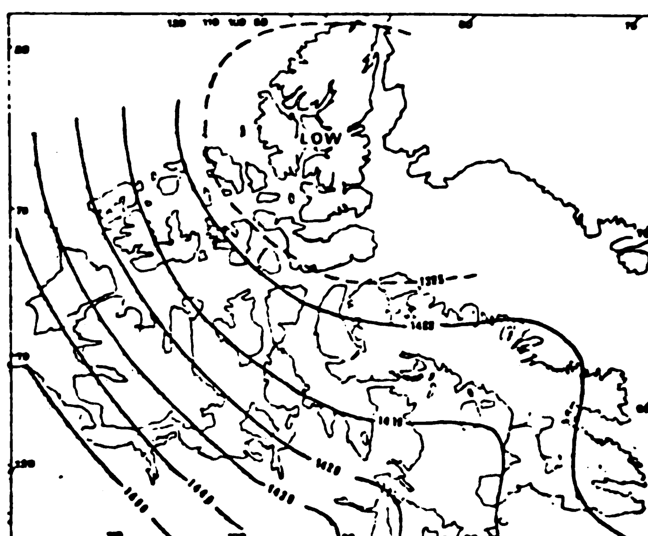


Fig. 2 Average height of the July 850 mbar surface, 1964-72, in geopotential metres.

Figure 18. Synoptic pressure pattern typical of July during cooler summers. Reprinted with permission from Bradley, 1973.

summers, on the other hand, were associated with a deep 700 mbar trough over eastern Canada. Such summers proved to be dry in Keewatin, but wet in Labrador-Ungava.

Thus, from the data on the correlation of temperature trends and airflow, winters (September-May) on the south coast of Baffin Island during a warming trend would be expected to show warming temperature trends and increased fall and early winter precipitation. Increasingly frequent southerly airflow would be expected to advect more warm, moist air over the area, helping to bring on these conditions. Summers (June-August) might show slight increases in temperature, but they would be expected to remain cool with less marked increases, if increases occurred at all. Here again an increase in westerly, particularly southwesterly, airflow would occur; but because of change in dominant pressure systems, from a ridge of high pressure lying to the east and south during the cooling, to a low lying to the east during a warming trend, increased cloudiness might well keep summer temperatures from rising significantly. Summers would undoubtedly also have increasing precipitation. Barry (verbal communication) concurs with this inferred pattern.

These trends in temperature and precipitation have some important implications for the animal resource populations which the Dorset occupants of the Nanook Site utilized. These implications will be examined in the next part of Chapter 4. The proposition that changes in the position of standing waves, rather than in variation of solar radiation, is responsible for climatic change in the eastern arctic also has implications for eastern arctic prehistory in general. These implications will be discussed further in Chapter 6.

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PART 4

ANIMAL RESOURCE RESPONSE TO CLIMATIC CHANGE

Three animal species, the ringed seal, *Phoca hispida*, (Schreber), the bearded seal, *Erignathus barbatus*, (Erxleben), and the caribou, *Rangifer tarandus groenlandicus*, (Linnaeus), probably contributed the bulk of the meat for Dorset larders on the south coast of Baffin Island. However, for several reasons, it is not possible to determine the proportional contribution which each species made to the yearly diet. First, for the Nanook Site (KdDq-9) and the Morrison Site (KdDq-7-3) faunal samples reported in this research constitute the only identified faunal material from the south coast; these samples are too limited to serve as the basis for such a determination. Although proportions can be derived from these, it is difficult to judge how representative these samples would be of proportions of animals already harvested. (See Section I, Part 2 of Chapter 5 on faunal analysis methods for further comments on this matter.) Second, it is difficult to tell at what season of the year the Nanook Site was occupied. While a reasonably supportable argument can be made for occupation during at least one season (see the Results Section of Chapter 5), it is impossible to show that the site was not occupied at other seasons as well. Finally, little or nothing is known about the total Dorset seasonal subsistence round in this area. Thus, even though the evidence suggests that the Nanook Site may have been occupied during one particular season, how the proportions in the faunal samples relate to the resources harvested during the rest of the year is unknown.

Nevertheless, because the goal is to learn how climatic change may have affected the animals which served the Dorset people of this area as important subsistence resources, all three species must be investigated. Further, in addition to these three major species, it is valuable to take a less detailed look at some species which appear to have been less important in terms of their overall contribution to Dorset subsistence. Since flexibility is an important aspect of most known Eskimo adaptations, these species may have been harvested during seasonal bottlenecks in the subsistence round; or they may have provided important alternative food sources when one of the major species failed to be available in sufficient numbers.[5]

The ringed seal. Although it is impossible to make a definite statement because we know nothing about the relative size or the availability of the various animal populations which existed during the Dorset period, the ringed seal may well have been the most important of the three major resource species. While it is the smallest of the three, providing the least amount of meat per animal, the ringed seal was probably also the most common and the most available. Ethnography shows that it has been the single most important food resource for the recent Inuit population of the area (Boas, 1964; Graburn, 1963; Kemp, 1971; Soper, 1928). Additionally, as a marine, rather than terrestrial resource, the ringed seal is part of an ecological system which is less subject to fluctuations, particularly in weather conditions (Dunbar, 1968).

The ringed seal is the commonest and most widely distributed of the arctic seals (Figure 19), although compared to other northern seal species it is relatively small. Mansfield (1964) reports that the average male is 54 inches long and weighs about 150 lbs., with females averaging slightly smaller. However, in the Lake Harbour area the average size tends to be somewhat smaller; Kemp (1971) found that the average ringed seal harvested at the time of his research weighed about 80 lbs., but his total can be expected to include a large proportion of immature animals.

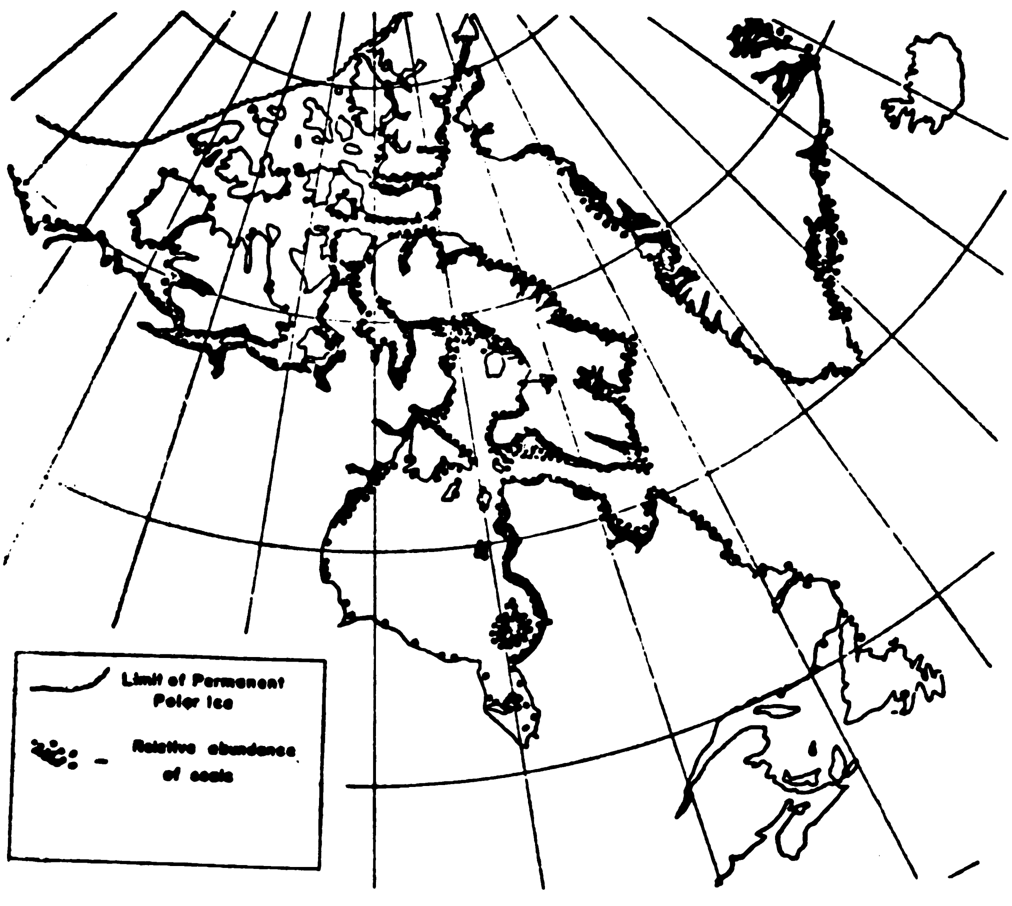

Figure 23. Distribution of ringed seals in the Eastern Arctic. Reprinted from Mansfield, 1964 with permission of the Minister of Supplies and Services, Canada.

The ringed seal feeds on a wide variety of resources: over 72 species have been identified from its stomach contents (Dunbar, 1941; McLaren, 1958a). Examining the eating habits of ringed seals off the southwest coast of Baffin Island, McLaren found that the planktonic amphipod, Themisto libullula, a copepod, Mysis oculata, and the polar cod, Boreogadus saida, were the primary foods. The polar cod comes from the shallowest depths; Mysis, which may be taken in onshore feeding, generally inhabits slightly deeper waters; Themisto comes from offshore habitats with still deeper water. Dunbar (1941) notes a similar feeding pattern among seals taken in the vicinity of Lake Harbour. Thus, the ringed seal exploits a variety of shallow marine habitats and foodstuffs (Dunbar, 1953; McLaren, 1958a).

The ringed seal pup begins its life in a den which the mother seal constructs in the fast ice. The lair consists of a hollow under a snow, bank or between old rafted floes (frequently in a former pressure ridge) which the female enters from below the ice, often through an enlarged breathing hole. The young are born near the beginning of April and nursed until mid-to-late June, usually the time when break-up of the landfast ice occurs. This lengthy nursing period contrasts sharply with the much briefer nursing period of the bearded and harp seals which bear and raise their young on the less stable pack ice. Ringed seals have a long adolescence; males reach sexual maturity at about 7 years, females at about 6 or 7 years. The normal adult lifespan may last well into the 20's; and, while only a few individuals live to such an age, animals over 39 years old have been recovered (McLaren, 1958a).

One of the most distinctive aspects of ringed seal behavior is its ability to live under the ice in bays and fjords during the winter by maintaining a number of breathing holes. It is primarily the adults that live inshore under the ice; immatures live mainly around leads and at the outer floe edge of the landfast ice. McLaren suggests that instincts connected with breeding and raising young attract the older animals to living under the ice, since there is some tendency for older animals to occupy the more stable areas closer to shore. There is even some suggestion that immatures may be dependent on the breathing holes of adults when they are trapped inshore by winter ice formation (McLaren, 1958a:70; Vibe, 1967:5).

Within a few weeks after the pup is born in the spring, the female mates for the following year. By the time the pup is a month or six weeks old, longer days, warmer temperatures, and sunshine encourage all the seals to spend time basking on top of the ice. At this time, the adults and adolescents fast and moult their old coat of hair. As a result of this fasting, they also lose a considerable amount of their fatty blubber layer.[6]

During the summer, both adults and immatures move a considerable distance off shore in many areas, including the area near the site. McLaren (1958a) reports that few seals are encountered within less than 3 miles of shore near Cape Dorset at this time of year. Dunbar (1941) has noted a similar phenomenon in the Lake Harbour area. Onshore movement commences with the onset of freeze up again in the fall. Thus, ringed seals would have been available to prehistoric inhabitants of the Cape Tanfield area all year, although obtaining them in the summer would have required the use of boats.

Fast ice plays a very important role in the ringed seal's life history. Unlike most seals which inhabit arctic waters and are adapted

to a floating pack ice environment, the ringed seal requires both winter land fast ice (for the adults to breed) and a winter floe edge with open water (for the immatures); the geographic distribution of this seal is coincident with these phenomena. As McLaren (1958a&b) documents in his research, the quality of the fast ice environment is the single most important factor influencing ringed seal population size. Further, the fast ice environment is the one factor affecting ringed seal populations which might be influenced by climatic change. Research on Greenland by Vibe (1967) concerning the relationship between changes in climate, ice conditions, and size of the local ringed seal population as indicated by fur purchase records and popular accounts confirms this proposition.

The size and quality of the fast ice in a given area is related in large part to the configuration of the shoreline. On the one hand, where the coast is highly irregular, with deep fjords or embayments and many offshore islands, a large area of stable, fast ice forms. Deep bays and inlets freeze early and securely, allowing snow to build up to an adequate depth for birth lairs. Offshore islands act as anchor points against the destructive effects of winds and tides. Not only does a large area of ice form early, but also it remains stable, thawing slowly and gradually in the spring. Such areas can support large breeding populations, because there is plenty of space for many animals to live and breed under the ice. Moreover, the ice remains stable during the long nursing period in the spring, allowing the pup to grow larger before it is weaned.

On the other hand, areas with simple coastlines and few or no off-shore islands have a smaller fast ice area which is not so stable. More vulnerable to the winds and the tides, the ice in such an area breaks up earlier and more rapidly in the spring. These areas support much smaller breeding populations, since there is less area for adults to live under the ice in winter. Likewise, the overall size of the seals breeding in these areas tends to be smaller due to the fact that break-up comes earlier, shortening the nursing period (McLaren, 1958a&b; Smith, 1973).[7]

In addition to fast ice, the ringed seal requires open water for the immature animals. Hudson Strait possesses this characteristic throughout most of its length. Rarely is it more than 80% frozen, even during the depths of winter (Campbell, 1958; Hare and Montgomery, 1949). This situation results from the high level of turbulence in Strait waters; the eastern portion of the Strait forms a bottleneck behind which tides rise to a level higher than in most areas of the eastern arctic. Tidal conditions may be so strong that they produce temporary density inversions during the diurnal tidal cycle (Dunbar, 1955a). Such tidal turbulence, in conjunction with strong currents and winds, prevents the Strait from completely freezing over.

Such turbulence has important implications for marine life. It insures a more thorough mixing of water layers carrying oxygen and organic nutrients to the depths, thereby preventing stagnating stratification. Such conditions help insure a richer and more diverse marine fauna in the area. However, this richness of fauna does not seem to be a factor crucial to the presence of the ringed seal, because of the diversity of its potential diet; several areas of the arctic which have a rich food supply nevertheless have very low ringed seal populations (McLaren, 1958a).

McLaren (1958b) classifies the area around Lake Harbour, together with

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with a larger area extending from Fair Ness to East Bluff. Overall, it is a relatively simple stretch of coastline with a relatively low availability index for ringed seals in both summer and winter. However, the area from Juet Island to Crooks Inlet is somewhat more complex than the surrounding area, in that offshore islands, especially Big Island, aid in stabilizing land fast ice. Dunbar (1949) notes that McKeller Bay, an interior bay not far from the site location at Cape Tanfield, is an especially good breeding area; and both Boas (1964:10) and Kemp (1971) note the development of land-fast ice in the area, with a constant floe-edge running from Big Island to Juet Island. The size and configuration of this land-fast ice in relation to the site location can be seen in an illustration from Kemp's (1971) article (Figure 2). The Lake Harbour area is also located fairly close to the segment of the south coast from Fair Ness to Sakkiak Island which has a strongly irregular coastline and a high seal availability index. Finally, the age population profiles in McLaren's (1958a) study show that there is a tendency for animals, particularly immatures, to move out of highly populated areas into less populated ones. Thus, the Lake Harbour area, at least within modern times, has had relatively good hunting because it attracts some animals from the highly productive areas further west along the coast. It seems reasonable to expect this situation to have existed in the past as well, since this long stable floe edge provides an important hunting location, especially from late winter through break-up in early summer.

In considering the effects of climatic change, shoreline configuration, of course, remains a constant. The remaining factors which affect the fast ice are primarily temperature, the insulating effects of snow cover, and storminess, with its accompanying unfavorable winds and water tu

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turbulence. Growth rates for ice in the arctic correlate well with air temperature, and expressions which relate such growth to the cumulative degree-days below freezing have been summarized by Bilello (1961). Surface waters in the Canadian arctic have an average salinity of about 32 parts per thousand (Collin and Dunbar, 1964), and thus a freezing temperature of -1.8° (Jacobs et al., 1975). Although new ice may form in early September off Baffin Island, the fast ice is usually not established until late October or early November. In some years an extensive "skin" or nilas of very thin ice will form, only to be broken up by subsequent autumn storms. The actual number of days of subfreezing temperatures required for complete freeze-up may vary greatly with location, and from one year to the next (Bilello, 1961; Jacobs et al., 1975).

The process of spring break-up is more complicated than the process of formation and growth. Solar radiation plays a much larger role than direct heat exchange with the air, although a close relationship between ablation and air temperature does exist. The changing albedo of the ice surface as it moves from fresh snow to melting snow to water greatly affects the process of break-up. Puddles with a much lower albedo than the ice surfaces absorb more radiation and play an important role. During the final stages, storms and wave action may also aid in the acceleration of the process (Jacobs et al., 1975).

The local climatic effects discussed in the previous section indicate that during a warming trend, such as that which appeared at the end of the Nanook Site occupation, warmer and wetter winters with more autumn storminess, and moderate summers with a fair amount of cloudiness and precipitation, are to be expected. Such a climatic regime would have a detrimental effect in that the growth of fast ice in the fall slows and the break-up in the spring occurs earlier. During the fall, with warmer temperatures, the number of cumulative degree days below -1.8° C would come increasingly later in the season. Increased storminess, with its accompanying winds and turbulence, would more frequently disrupt the formation of new ice, delaying its growth (Holtzmark, 1955). Spring break-up also would be affected, but less drastically. Greater precipitation, especially as it became warmer and tended to be more saturated, would help to hasten break-up, as would the presence of a major low pressure area. However, these effects would be modified to some extent by increased cloudiness, hindering the incoming solar radiation.

In addition to factors directly related to climatic change, there is some possibility that changes in the currents in Hudson Strait, an indirect consequence of climatic change, might also affect the fast ice. While simple empirical equations, such as Bilello's (1961), seem to be the most satisfactory for predicting fast ice growth, Jacobs _et al_. (1975) find a somewhat more complex equation based on one dimensional heat flow to be conceptually more satisfactory for understanding the processes involved. This equation shows that the temperature and salinity of the water present at freeze-up time are basic variables, and these variables could well be altered by changes in current flow.

There are two main surface currents in Hudson Strait, as Figure 20 drawn from Campbell (1958) illustrates. The stronger of the two flows out of Hudson Bay, between northern Ungava and Nottingham Island and along the northern coast of the Ungava Peninsula. One arm of this current dips south into Ungava Bay, but eventually it joins the flow of the Labrador current on down the east coast of Labrador (Campbell, 1958; Dunbar, 1966). The weaker current is an arm of the Baffin Island current; it flows westward along the southern Baffin Island coast. At various points, it turns south and joins the predominantly eastward flow out of Hudson Bay. While most of the flow has turned southward by the time it reaches Big Island, there is some physical and biological evidence that it may penetrate as far as southeastern Foxe Basin. It is reasonable to postulate that this southward flow off Big Island may in part be responsible for helping to maintain an even, receding, spring floe edge (Pat Welch, verbal communication). This edge, visible in Figure 2, drawn from Kemp's work, makes this particular floe edge a good spring hunting area even today.

Oceanographers studying currents have characterized waters in terms of temperature, salinity and other characteristics; labeling them "arctic water", "West Greenland water", and so on. The stronger of the two currents in Hudson Strait is predominantly "arctic water" (Figure 21). It is water which has drained south out of the arctic archipelago into Hudson Bay, where it has been circulated according to a counterclockwise pattern. Locally it has undergone some changes in temperature and salinity, due to drainage from the land and surface warming, but it retains an essentially arctic character. However, the Baffin Island current, by the time it reaches the opening of Hudson Strait where one arm turns westward along the south coast of Baffin Island, is a mixture of water types. Not only does it contain arctic water draining Robeson Channel, but also it includes an unknown proportion of water from the West Greenland Current, fed by the Irminger Current and water from the Labrador Sea, and both of these carry a large volume of water

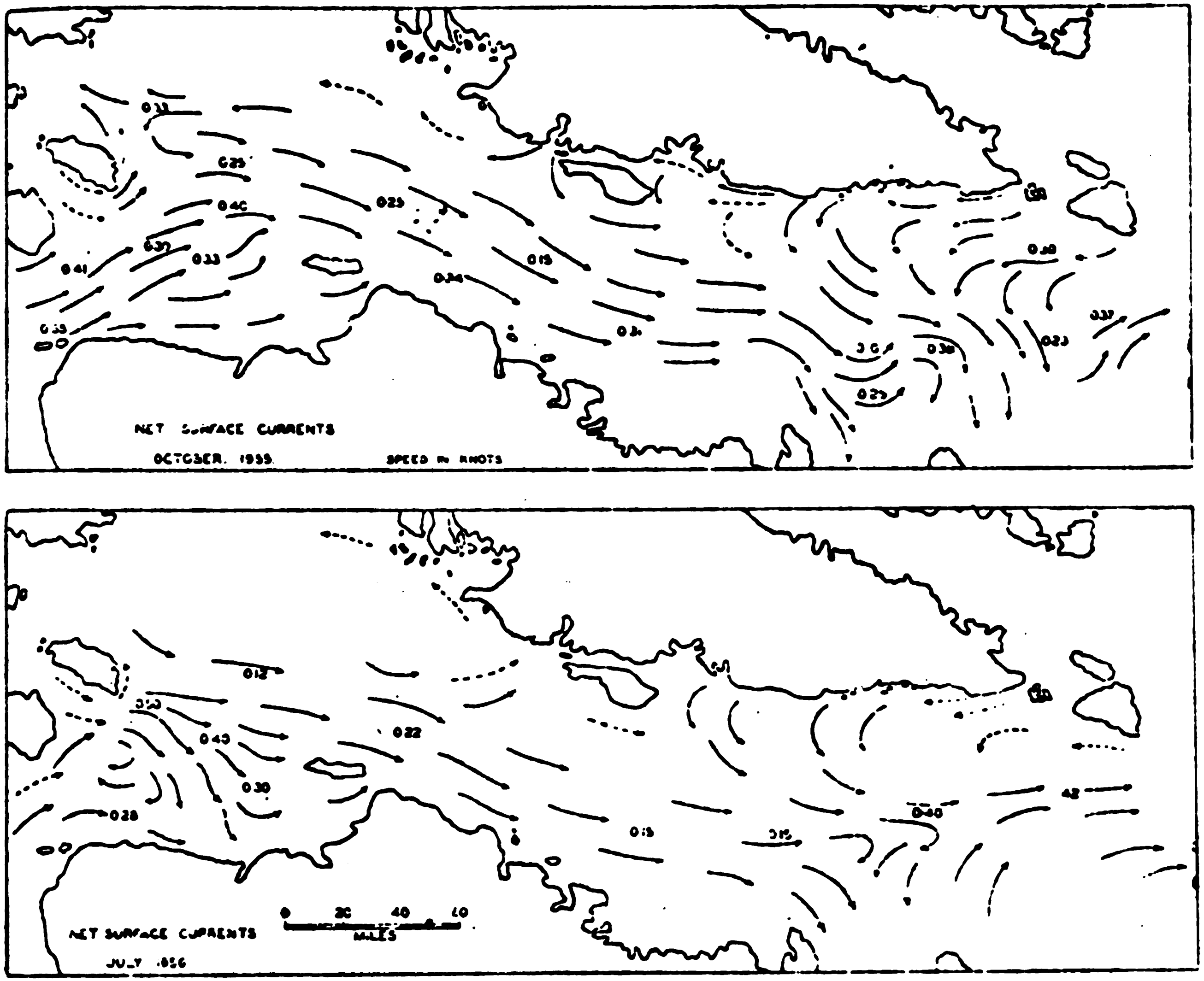

Figure 20. Net surface currents, Hudson Strait. Reprinted from Campbell, 1958, Figures 40,41, with permission of the Minister of Supplies and Services, Canada.

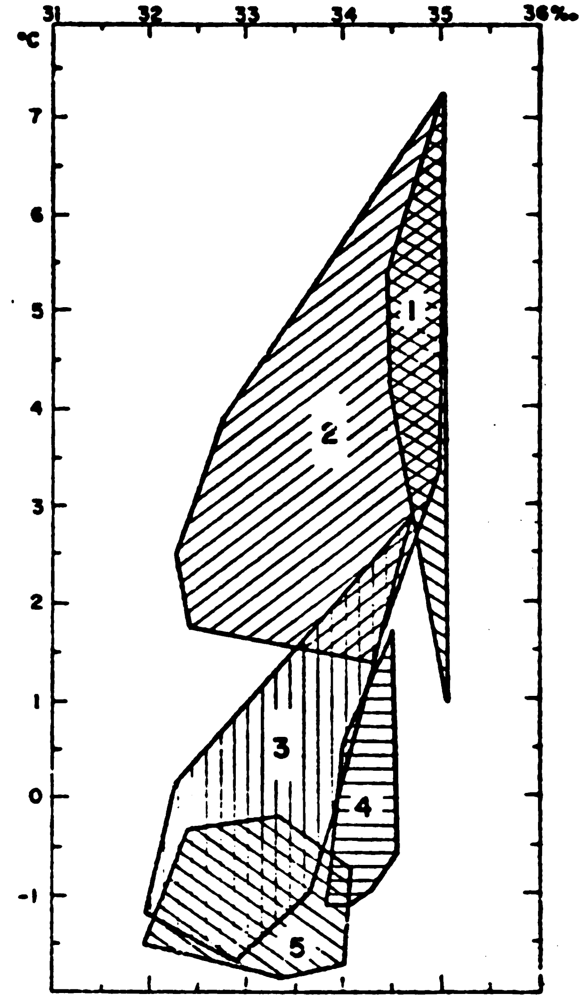

Figure 2 Temperature-Salinity diagram showing water masses in the Canadian Eastern Arctic. Water from surface to 49 metres is omitted. 1. Labrador Sea. 2. West Greenland, Disko Bay to Cape Farewell. 3. Labrador Current. 4. Deep Baffin Bay water, 300 metres to bottom. 5. Arctic Water, found in upper 200-250 metres in the Arctic archipelago, Canadian current and Hudson Bay and Strait.

Figure 21. The relationsips among various water types. Reprinted from Dunbar, 1966, Figure 2, with permission of the Minister of Supplies and Services, Canada.

which originates in the warmer Atlantic (Dunbar, 1966:19).

Campbell (1958) notes that between Resolution Island and Big Island along the south coast, a long open lead or region of light ice concentration tends to appear with freeze-up and break-up.[8] The cause of this phenomena is believed to be related to wind patterns, and the intrusion of water from Baffin Bay. Turbulence west of Fair Ness may also contribute, but the entire picture is not completely understood.

If this arm of the Baffin Island Current, which enters Hudson Strait and flows westward along the south coast, were to become significantly warmer than it is at present, the amount of fast ice along the south coast could be expected to decrease and, along with it, the size of the ringed seal population. While changes in currents of the magnitude of those which have affected parts of southwest Greenland are not expected, due in part to the more complex situation in Hudson Strait, the Greenland example shows that changes in current clearly can affect the presence of fast ice.

Dunbar (1954a:29; 1955), in a note on climatic change has indicated that major changes in current flow have not been observed during recent warm periods. Instead, there appears to be an increased flow of Atlantic water northwards which brings about two related effects:

1) There is an increased flow of water out of the Arctic Ocean, and

2) The Canadian Arctic Current and the West Greenland Current (containing a large proportion of Atlantic water from the Irminger Current) are more subject to the Coriolis Effect and thus press with greater force against the Baffin Island and West Greenland coasts respectively. When this phenomena takes place, it has the effect of forcing more arctic water from the Canadian Arctic Current into Hudson Strait and Ungava

Bay and minimizing the westward flow of West Greenland water over to the eastern end of Hudson Straits (Figure 22).

Dunbar indicates that the result of this circulation pattern is that the warmer Atlantic waters appear to enter Hudson Strait in any influential quantity only briefly, either at the very beginning or at the very end of warmer periods, when the circulation flow lessens enough so that a greater proportion of Atlantic water can enter the Straits. The appearance of Atlantic cod, Gadus callarias, serves as an indicator of warming marine conditions in the northern part of its range. During the 1880's, which marked the beginning of a warming trend that lasted until about 1945, cod appeared briefly in significant numbers in Ungava Bay, but cod were not found there again in significant numbers until 1959 (Dunbar, 1966), at the end of a warming trend.

While this type of current change would not be expected to have extended long range effects, when coupled with the onset of a warming period for a short period of years, it might aggravate the detrimental effects on fast ice in general, causing an earlier less orderly decay of the floe edge between Big Island and Juet Island, in particular. The expected result would be at least a moderate decrease in the ringed seal population.

The bearded seal. The bearded seal, Erignathus barbatus (Erxleben), is the other marine mammal among the three most important resource species. It is the biggest of the eastern arctic seals, with the largest adults reaching a maximum weight of 750 lbs. Sexual dimorphism, if it exists, is slight. The bearded seal is a solitary animal which prefers areas where shallow banks are free of land-fast ice in the winter. It is associated with moving ice on which it hauls out to rest

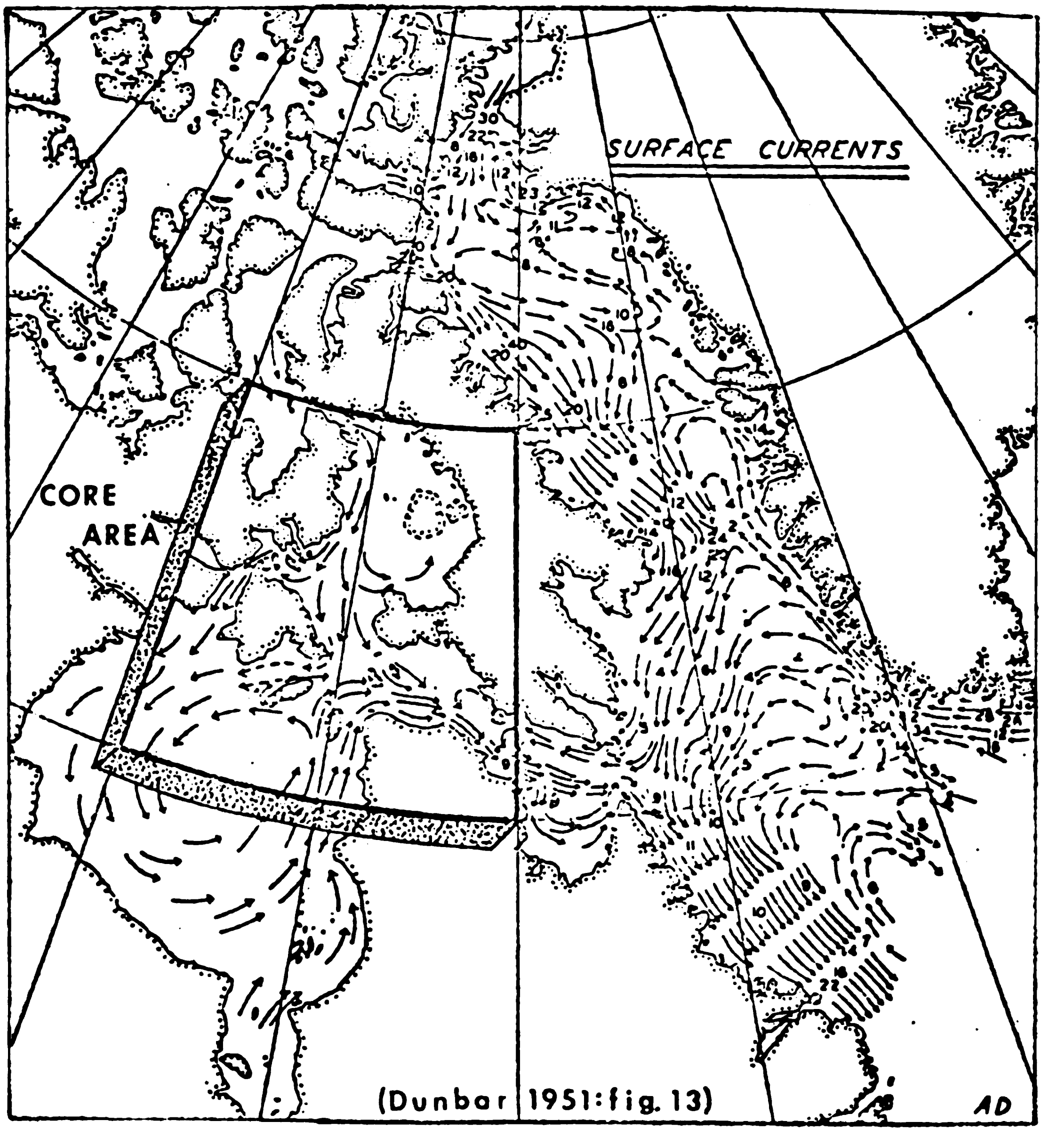

Figure 22. The major currents in the eastern Arctic and Subarctic. Reprinted with permission from Dekin, 1975.

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and to breed. Thus its habitat complements in many respects that of the ringed seal, but nowhere in the arctic is the bearded seal as common as the ringed seal (Figure 23). The bearded seal's food habits are similar to those of the walrus, and its mustacial whiskers, like those of the walrus, help adapt it to a bottom-feeding way of life. Shrimps, holothurians, clams, whelks, snails, octopus, and such bottom fish as sculpins, flounder, and polar cod form the bulk of its diet (King, 1964: 43-45; McLaren, 1958c:52ff.).

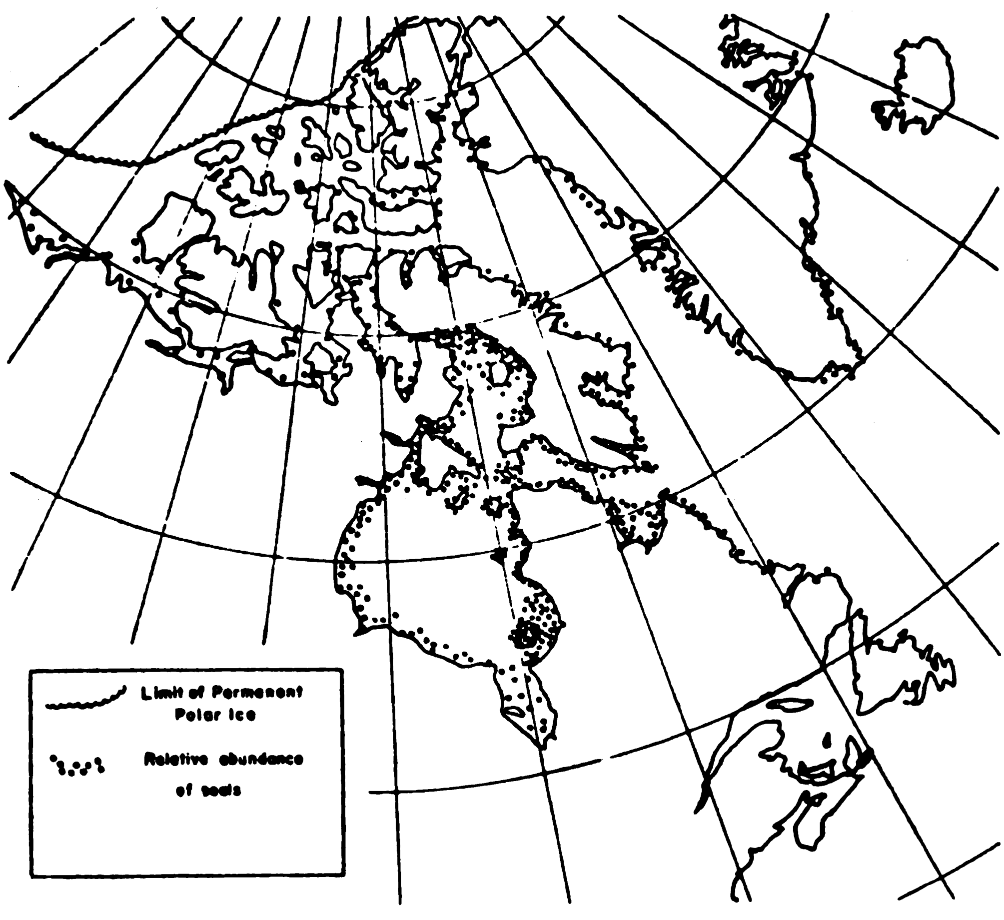

Figure 19. Distribution of bearded seals in the Eastern Arctic. Reprinted from Mansfield, 1964 with permission of the Minister of Supplies and Services, Canada.

The young bearded seal is born in late April or early May on the moving pack ice, and it has a shorter, probably more intense nursing period than has the ringed seal pup. Because of the uncertainties of its pack ice nursery, the young bearded seal must be ready to fend for itself at an early age. During the first summer of its life, it generally doubles its birth weight of about 100 lbs. Adolescence in the bearded seal lasts about as long as in the ringed seal, with males reaching sexual maturity at about 7 years and females at 6 or 7 years. Like the ringed seal, breeding seems to take place very shortly after the time the pups are born. However, unlike the ringed seal, females which have just given birth seem to ovulate after the male rutting season is over, thereby insuring that they give birth only every two years.

Contrary to the case in the ringed seal where the presence of proper food was not a significant factor, the occurrence of the bearded seal may be limited by the presence or absence of its benthonic food. In attempting to highlight factors which might affect bearded seal occurrence, McLaren (1958b) cites Vibe (1950), who places a limit of 80 meters on the depth to which the bearded seal can dive for food. The bearded seal also may be limited by the presence of fast ice, since it generally does not maintain breathing holes in the winter. Therefore, a crude indication of bearded seal availability can be derived by measuring the size of the areas of open water in winter which are within the 80 meter depth limit. Using this method, McLaren (1958b) generates an availability index for bearded seal similar to the one which he created for ringed seal, and finds that the south coast of Baffin Island has a low availability index. Such a low index is understandable in view of the turbulent conditions along much of the south coast. With heavy tides and considerable current activity, this area does not provide an ideal habitat for many of the organisms on which the bearded seal feeds.

Even though the occurrence of the proper foods is important, it appears that the only element among the limiting factors mentioned above which would be altered by climatic change is again the presence of fast ice. As the discussion of the ringed seal has shown, a warming trend tends to decrease the number of days when fast ice is present, a trend with slightly positive consequences for the bearded seal. However, since the bearded seal is not common in this area to begin with, due to the lack of ideal feeding conditions, from the point of view of a human predator population, the expected impact on the bearded seal population of change in the fast-ice conditions would be minor.

The caribou. The third major resource species of importance to the Dorset population residing at the Nanook Site was the caribou, Rangifer tarandus groenlandicus, (Linnaeus)(Banfield, 1961). As an organism from the terrestrial subsystem of the arctic ecosystem, the caribou is subject to greater variability because it is not protected by the buffering effects of the marine environment. The barren ground caribou which inhabits Baffin Island is medium-sized compared with other races of caribou and reindeer. Males average 225-238 lbs., while females average 150-171 lbs. in weight (Loughrey and Kelsall, 1968; Banfield, 1974:385. Kelsall, 1968:29).

During the summer, caribou feed on the new growth of grasses and sedges, on the leaves of many woody perennials, on fungi, and to some extent on lichens. At this time of year they move constantly, grazing by choosing a mouthful or two, then moving a few steps before taking another. During the winter, behavior is adapted to obtaining food under the snow. When snow depth is not great, caribou feed on exposed vegetation, pawing with their forefeet to expose additional plants. However, as snow depth increases, caribou use their forelegs alternately, to paw crater-like pits through the snow in which to feed. Terrestrial lichens form the most important component of their winter food, but a large variety of woody plants, grasses, and sedges contribute to their diet (Banfield, 1974:385-386; Kelsall, 1968:67-79; Loughrey & Kelsall, 1968:276-77).

Barren ground caribou are nomadic, and under most conditions migratory. Spring migration usually begins in mid-March, when the pregnant cows and their calves from the previous year begin their move toward the calving grounds. Calving grounds are usually specific, preferred areas, generally high dry terrain with a more rugged relief than the surrounding country. Calving takes place during the month of June. During July and August the animals tend to disperse widely, sex and age groups intermingle, and movement tends to be haphazard. The rut begins in early October, and by December the caribou have returned to their winter range.

Caribou calves are precocious, and they are able to follow their mothers within a few hours after their birth. By the time they are a year old, males tend to form small juvenile bachelor bands or join the adult bulls and non-breeding females, whereas female yearlings tend to accompany the cows to the calving area and remain associated with maternity and nursery groups. Both males and females become sexually mature at 17 months, but males do not become successful breeders until 4-5 years of age; about 50% of the females do not become pregnant until they are four years old. Banfield (1955) found that the average life expectation for mainland barren ground caribou was 4.1 years, but since normal calf mortality may be as high as 50-70%, calf mortality tends to lower the average considerably (Kelsall, 1968; Loughrey & Kelsall, 1968). The first week of life is perhaps the most rigorous for the calf. If it is cold and wet, particularly if there is wet snow or rain at the time the calves are born, calf mortality from exposure is likely to be high. Furthermore, drowning and exposure deaths at stream crossings during migration are highest among the calves. Finally, winter seems to be harder on animals in their first year or two than on adults (Kelsall, 1968; Loughrey & Kelsall, 1968).

While migratory behavior is typical of most caribou, when herd size dwindles, the herd no longer moves along past migration routes. Instead, the herd tends to remain in small, widely scattered groups which do not show a mass migration pattern. Historical records of Baffin Island reveal that large numbers of caribou undertook definite migrations. However, as of 1960, the Baffin Island herds had undergone drastic reduction. Apart from the herds near Nettilling Lake and perhaps those near Inuktorfik Lake, only very small, isolated herds took part in any recognizable migration (Tener & Solomon, 1960).

During much of the 20th century, caribou herds in both Alaska and Canada have declined (Loughrey and Kelsall, 1968; Lent, 1966; Kelsall, 1968, 1970) and zoologists in both countries have attempted to understand why. Several factors seem to be responsible. Undoubtedly the advent of firearms was an important element, but the introduction of trapping with the requirement for larger dog teams which had to be fed significant amounts of protein food, as well as the meat demands of whalers and other non-natives also had a significant effect.

None of these causes would be involved in resource variation under prehistoric conditions. In his studies on Greenland, Vibe (1967) has shown that reindeer (in this case, animals which may well have migrated to Greenland from Canada across the ice of Davis Strait) are indeed very sensitive to climatic change. Vibe also points out that caribou require relatively dry, cold conditions, with some summer rain and fog, often brought by foehn winds, to foster the growth of the lichen which they require, especially during the wintertime. During periods which are too wet and too snowy, caribou either die out or retreat to more favorable areas.

Biologists studying caribou behavior are beginning to supply us with some of the details of the processes which bring about this situation. Pruitt (1959a), for example, has shown that snow cover is an extremely important factor in caribou ecology. Caribou movement seems to be very heavily influenced by the character of the snow cover, and caribou avoid areas with undesirable conditions. Pruitt found that caribou respond to differences in snow texture, hardness and depth by moving away from conditions which are less desirable; when rain or warm temperatures make the snow crusty or coarse, caribou move out into other areas. About 60 cm. of snow seems to form a critical upper depth limit for effective exploitation of the food beneath. Further, by their movement and by digging feeding craters, caribou alter the snow so that they rarely return to the same area to feed more than twice. After two feedings, the snow has become so hard and compacted that conditions are undesirable, and the animals move on.

Processes stemming from the same instinctual response to snow conditions seem to form an important part of migration mechanisms as well. While a tolerance for less desirable conditions develops over the winter as the snow cover matures, the conditions brought on by warmer temperatures and higher levels of insolation, namely settling, crusting, and the first signs of melting, seem to be key factors in the onset of migration in the spring. Thus, snow conditions can prevent caribou from using large areas of winter range which might otherwise be available to them, and snow conditions can exert a major influence on caribou patterns of movement over a significant portion of the yearly cycle.

Pruitt's findings have been borne out by the work of Henshaw (1968) in the Kobuk River Valley of Alaska, by Lent (1966) and by the work of various Canadian researchers (Kelsall, 1968, 1970 for example). Henshaw notes that the animals seek uneven terrain, with exposed areas where the wind has blown away the snow cover for feeding and with more sheltered areas for resting. Temperatures as low as -50°F. seem to cause them no problem. During storm conditions they seek lower terrain, and when wind speeds reach a given level, they lie down in places where the land form or, if present, trees provide some protection from the wind.

From an understanding of these processes, it is possible to see how the warming trend which took place at the end of the occupation of the Nanook Site would bring about conditions highly unfavorable for caribou. Warmer autumn temperatures would mean that more precipitation would fall as rain, with a greater chance that an ice crust would form over feeding areas prior to snow fall. Snow fall, once it began, would be heavier, with a coarser texture and more internal and surface crusting. Finally, overall snow depth would be greater than during a cooling trend. All of these conditions are undesirable for caribou, and would lead them to seek other areas, perhaps undergoing a significant decline in numbers.

A warming trend would also bring about spring conditions detrimental to caribou. With the increased frequency of low pressure systems during the summer months of June, July, and August, the chance of wet conditions during calving time in mid-June, leading to higher calf mortality, would increase. Thus, a warming trend in the climate, such as the one expected at the close of the Nanook occupation, would have brought about conditions which were less favorable for caribou and a notable decline in caribou numbers.

Other species. Other resources which were used at the Nanook Site were also undoubtedly affected by the warming trend. The potential effect on walrus is unknown, but guessing from the case of the bearded seal which has a similar diet, the effect would not be negative and might be slightly positive. The effect on the polar bear is also unknown. Whether the decrease in the ringed seal population would be sufficient to affect this predator is unknown.

Small mammals, such as foxes and the lemmings on which they prey, would have had a somewhat easier time. These species undergo fairly regular periodic cycles which would continue; however, during a warming trend average population size would be larger. While warmer temperatures would mean deeper but crustier snow conditions in the winter, they would also mean less temperature stress, a longer summer for food storage and reproduction, and a better winter food supply. Arctic hares, which like the lemmings are primary consumers, would react in a similar fashion (Foromozov, 1964,1968; Irving, 1966; Morrison, 1964,1966; Pruitt, 1957,1959b,1960,1968; Rikhter, 1963).

Among the birds, there would be little effect from a warming trend, since most of them are migratory. Ptarmigan, however, would be affected; and a warming trend would be expected to produce more favorable conditions for this species, since the increased snow cover would produce better conditions for burrowing in the winter to escape cold and predators. Warmer temperatures would also produce a slightly shorter winter, a better food supply, and less temperature stress (Morrison, 1966).

Several other potential resource species inhabit the area: narwhale, beluga, baleen and sperm whale among the sea mammals, wolf and weasel among the land animals. However, evidence of these species was not found among the faunal material, and therefore they have not been considered.

In summary, the major resource which would be most severely affected by a warming trend is the caribou. Warmer temperatures, and heavier autumn and winter snowfall would bring about the more frequent occurrence of the kind of winter conditions which caribou tend to avoid, forcing them to move out of the area. A greater chance of wet weather at early summer calving time would also mean higher calf mortality and a further reduction of the number of caribou present in the area. The ringed seal also would be negatively affected, although less markedly than caribou. Warmer temperatures, heavier snowfall, and greater storminess in the autumn and early winter months would mean later freeze-up, while slightly warmer temperatures, more precipitation, and increased storminess in the late spring and early summer could be expected to hasten break-up. All of these effects would be expected to have a detrimental effect on the size of the local ringed seal population.

On the opposite side of the ledger, warming conditions would be expected to have no negative effects, and probably mildly positive effects, for bearded seal, arctic fox, arctic hare, ptarmigan, and perhaps walrus. However, since ringed seal and caribou are both major resources, and since each species, individually, would appear to have been a more important source of meat than the bearded seal for the Nanook inhabitants (see Faunal Analysis Section in the Appendix for supporting data), the negative effect of a warming trend on these two species far outweighs the positive effects on other species. Thus, overall, a warming trend can be said to have a detrimental effect on the animal resources available to the Dorset inhabitants of the Nanook Site.

Finally, going beyond the effects on the animals themselves, a warming trend also would be expected to have a detrimental effect on the ability of the people to hunt. As Dekin (1975) has pointed out in his model, less stable and predictable weather conditions, with increased storminess, higher winds, and poorer visibility, make hunting more difficult and the chance of a catch less secure. Additionally, the fast ice provides an important means of access to the significant marine resource species. A decrease in the number of days when this means of access is available could also be expected to have an unfavorable effect on hunting.

Once again, it should be emphasized that the warming trend under discussion may not have affected all areas of the eastern arctic in the same way, and its effect on animal resources surely differed from area to area. For example, farther north it may have had quite a favorable effect, making areas which were previously uninhabitable more favorable for animal resources and their human predators. Nevertheless, on the south coast of Baffin Island, it would appear that a warming trend would have had a detrimental effect on the animal resources and the ability of people to hunt them.

PART 5

DESCRIPTION OF THE SITE

Up to this point in the description, very few aspects of the Nanook Site itself, aside from the dating, have been presented. Therefore it would be valuable to examine some of the basic facts about the site itself. Additional information can be found in the Site Report Appendix.

The Nanook Site is situated on the west side of the Tanfield Valley, a small U-shaped valley running roughly north-south perpendicular to the shore about ½ mile east of Cape Tanfield and about 15 miles southeast of the Inuit community of Lake Harbour on the south coast of Baffin Island (Figure 24). The site location is bounded by two rock outcrops which form a pocket in the rocks 52' east to west and 182' north to south (Figure 25). The western outcrop is essentially a continuation of the western wall of the valley and forms a vertical wall 6-10' high adjacent to the site area; the eastern outcrop is low and rounded with a height of 3-4' (Figure 26). The surface of the pocket is covered with a 6-10 inch layer of grass and moss sod. There is no natural drainage and the site is quite wet during the months when the sod is not frozen (Maxwell, 1973:155-156).

Excavations have been conducted at the Nanook Site during four different field seasons spread over eight years. The site was first discovered in 1962 when Maxwell and a student field crew were surveying and excavating on Cape Tanfield. Additional field work was conducted in 1963, and by the end of that season nearly 1700 artifacts had been excavated from what are called the 9-1 and 9-2 portions of the site.

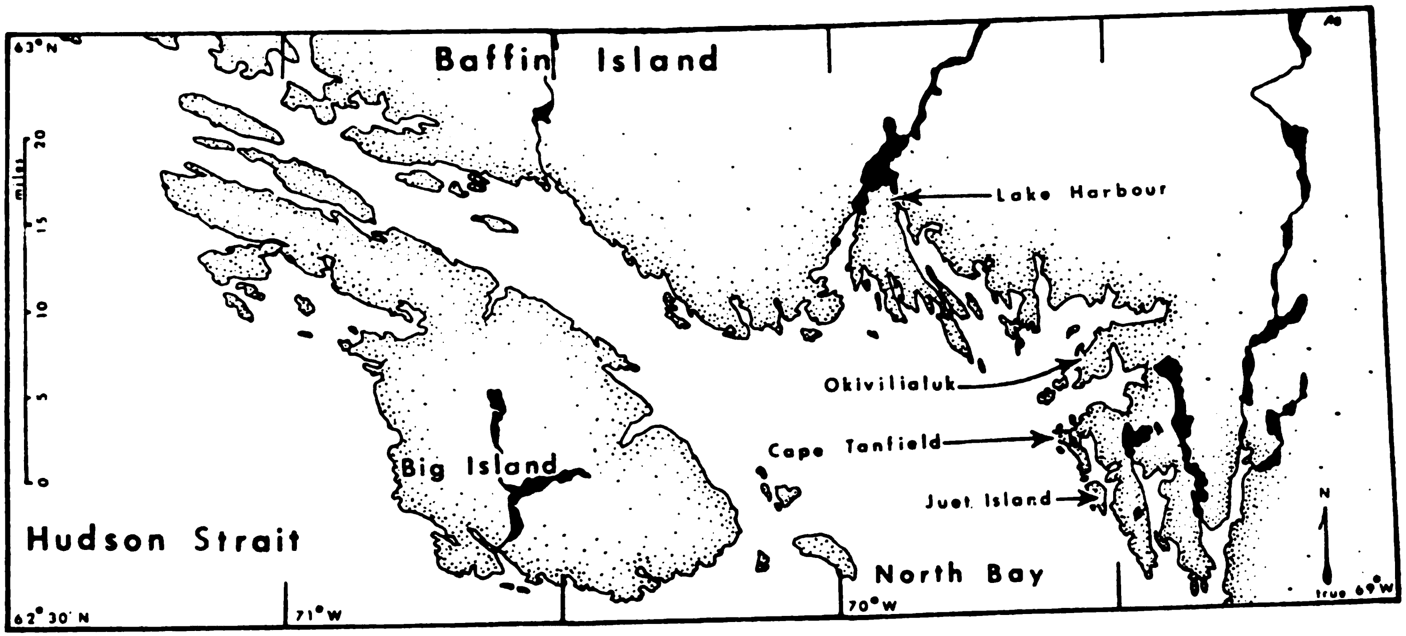

Figure 24. Map of the area in which the Nanook Site is located. Reprinted with permission from Dekin, 1975.

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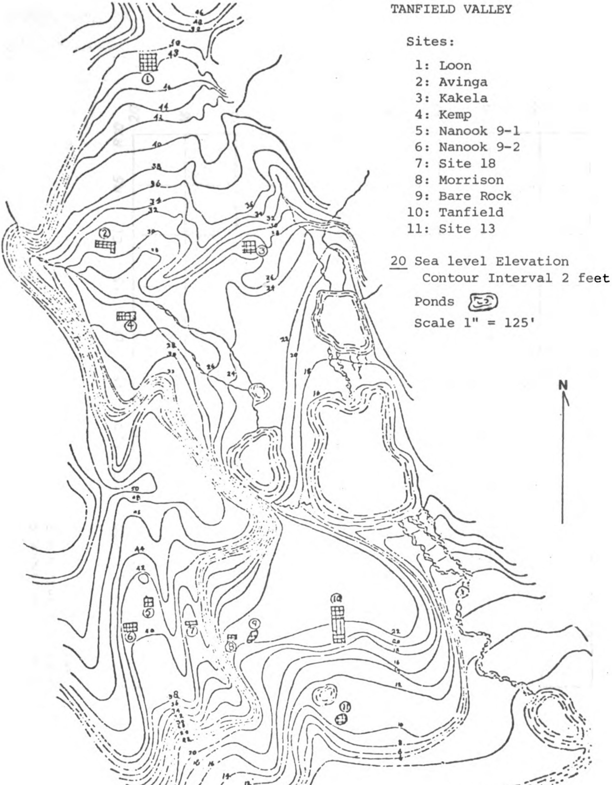

Figure 25. Map of Tanfield Valley with sites indicated as of the end of 1964 season. Based on Maxwell, 1973, Figure 15.

KdDq-9, The Nanook Site
Baffin Island, N.W.T.
Canada

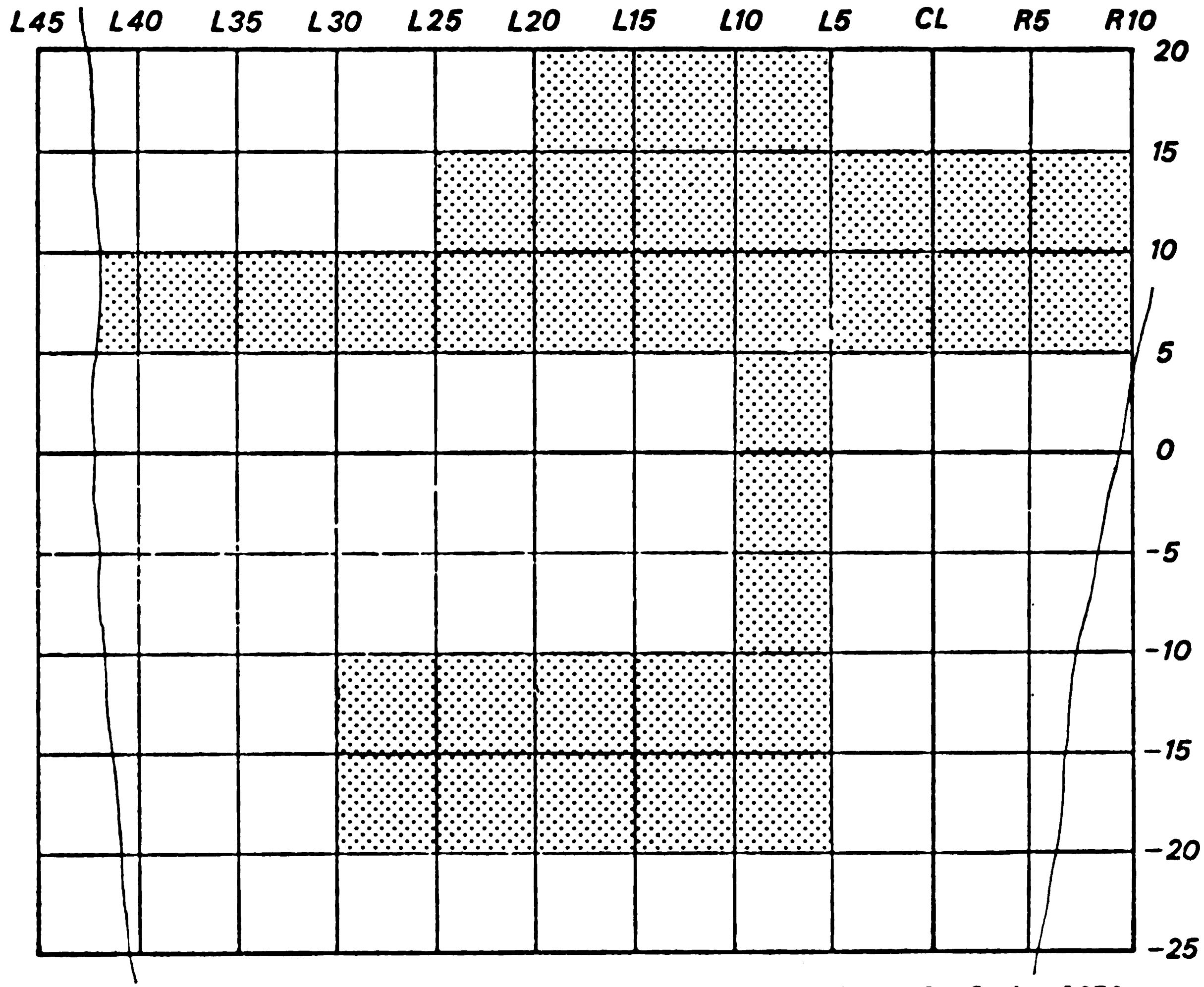

Figure 26. Grid map of the Nanook site showing areas excavated by the end of the 1970 season.

This material is described by Maxwell (1973) in a report including all the 1960-1963 excavations in the southern part of Baffin Island.

The Nanook Site was next worked again in 1966. During that season some additional work was done in 9-1 and 9-2, but the majority of the effort was expended in the excavation of the 9-3 portion. Approximately 1500 artifacts were added to the Nanook sample and the results were summarized by Arundale (1971).

The most recent excavations were conducted in the summer of 1970 by this researcher working with Maxwell. Additional areas in all parts of the site including balks and incompletely excavated squares were a major portion of the 1970 effort. New squares were opened primarily in the 9-3 portion of the site, and in contrast to previous years, faunal remains were collected.

The Nanook Site is essentially a very heavy midden deposit containing a wide variety of materials. Old sod layers, some of them cut and brought in from nearby, some of them probably natural growth, occur in all three portions of the site. Bone occurs throughout the site, although an extremely dense bone layer usually about six inches thick and found at a depth of 6-12' appears in some parts of all three portions as well. Another common feature, that Maxwell has used to define the perimeter of spaces which he has interpreted as structures, are areas with "pavements" of rocks which occur in fairly dense masses, sometimes piled two, three, and four deep. Concentrations of charred fat, probably seal fat, constitute another feature that occurs as areas of midden which are a black greasy mass. The charred fat encrusts some of the rocks and artifacts within these areas. There are also three concentrations of wooden shafts and wood fragments, as well as additional concentrations of wood chips and woodworking debris.

In addition to these features, fragments of a number of different organic materials such as leather, fur, fiber yarn or twine, small birch bark rolls, and worked pieces of baleen, wood, bone, antler, and ivory occur. Other artifactual evidence includes the whole gamut of lithic and non-lithic artifacts described in the Site Report Appendix. The condition of these artifacts varies from apparently newly made to badly deteriorated and unrecognizable.

The depth of the deposit and the sheer amount of material present indicate that the site has had numerous occupations, but determining how many and how long each one lasted is impossible. The various occupations of the site appear to have used the site location in different ways, so that when any given segment of the site is sampled, the result appears to be an almost random sample of the artifacts left by the range of activities carried on at the site. Such a site structure is, in part, what makes this analysis possible.

In the course of excavating each of the three site segments, Maxwell (1973, and personal communication) has found evidence which he has interpreted as the remains of a structure. In particular, Maxwell was searching for the remains of a domestic habitation. In his continuing excavation of the nearby Morrison Site, KdDq 7-3, Maxwell uncovered a set of formal features that he feels are evidence of a 'house' which strongly resemble some of those found in 9-3. These include: 1) a perimeter of built up rock and sod which may have been a bench, 2) lamp fragments found at several points around the perimeter on or near the 'bench', 3) a single area with a heavier concentration of seal fat residue and rocks encrusted with burned fat, 4) a central area which appeared to be a floor at a somewhat lower level than the bench and which contained wood working debris, and 5) a concentration of worked pole fragments which have been interpreted as the caved-in supports of the house covering. Since excavation of the 9-2 portion, particularly level 2 is incomplete, some of these same features may yet appear in that segment, as well. However, whatever structure (or structures) exists in the 9-1 segment is clearly quite different, and not readily interpretable at this point.

One of the problems with interpreting the data from the site is that in addition to its complex structure, it is difficult to determine the extent to which that structure results from natural, not cultural, causes. For example, it is clear that there are fewer faunal remains in level 1 of all three segments because level 1 is affected by the freezing and thawing of the active zone (see the Soils Section of the Site Report Appendix for further information on the active zone). Similarly the obvious frost crack in squares 5L10 and 10L10 indicates that some frost action has taken place. However, the extent to which other, more subtle forces may have been at work, is more difficult to detect. For example, cracks in the soil were found in the course of excavating both 10L5 and 5L5. To what extent these were due to recent processes which had taken place since these areas were stripped of sod and had thawed is unknown.

Before description of the site continues, some indications of the problems which have guided the research should be given. This account should provide the reader with some indications of the biases which may have affected data collection. Maxwell first went to the Lake Harbour area in 1960 when he was asked by the National Museum of Canada to examine a Juet Island site which was discovered in 1957 by Dr. Graham Coock, a wildlife biologist, and two Lake Harbour residents, Davidee and Mingneriak. Maxwell's initial field season (Maxwell, 1962) yielded what appeared to be an excellent temporal seriation from the sites he initially explored, and he returned to try to expand and strengthen his chronology, as well as explore additional areas. As work in the Lake Harbour area proceeded, Maxwell's interest in interpreting the internal structure of the sites grew, and more detailed information on factors such as precise artifact location, was gathered.

By the time this researcher undertook work on the Nanook Site in 1970, understanding the internal functional relationships within the site was the major goal of the research. Careful excavation techniques and the use of sophisticated statistical and spatial methods were expected to yield information on structures and activity areas within the Nanook Site which could be used to better interpret both its internal structure and its relationship to the local environment. However, the complexity of the site and some of the limitations on the data forced a change in goals, and the problem which serves as the basis for this study was adopted instead.

Since the configuration of the internal structure of the site is relatively complex, and this structure is not highly significant for the problem under consideration the following description will be general. The reader desiring additional information is urged to turn to the Excavation Narrative and Feature Description Section of the Site Report Appendix.

Finally, the difficulties resulting from the use of different systems of reckoning vertical provenience should be mentioned. As the previous discussion has indicated, the Nanook Site was originally excavated in three different horizontal units which were designated components and labeled 9-1, 9-2, and 9-3. Since these areal designations have a great deal of descriptive utility, this study will retain them as labels. However, since evidence supporting a separate occupational identity for each of these units is not clear, these labels should be regarded as purely descriptive. To prevent confusing these horizontal units with the vertical units which are more conventionally called components, 9-1, 9-2, and 9-3 instead will be referred to here by other terms such as "segment" or "portion".

These segment names were applied as digging progressed, and new parts of the site were opened. The original site grid included only the four squares originally excavated in 9-1 and some of the surrounding area. When 9-2 was opened, it was gridded separately. Hence the grid for these four squares in 9-1 does not coincide with the rest of the site grid by about 1 ft. This difference in grids is apparent on the maps of the site.

The main portion of the site, including part of 9-1, 9-2, and 9-3, was gridded in five foot squares with an east-west trending center line which lies about 15 ft. west of the eastern outcrop, and a zero line which bisects the presently excavated area of the site in a north-south direction. Initially, due to drainage problems, each square was taken down individually, making it difficult to carry the stratigraphy. In 1966, however, with the excavation of 9-3, 6 inch balks between the squares were used to aid excavation.

Most of the excavation of 9-1 and 9-2 was carried on during the 1962 and 1963 field seasons. Differences in typology and a difference in

300-400 years in the carbon dates for the respective areas led Maxwell, in his initial analysis, to continue to consider what were initially purely artificial excavation units as temporally distinct entities. The evidence available at this earlier date tended to support Maxwell's hypothesis. With the additions from later seasons to both the 9-1 and 9-2 samples, as well as the availability of material from a new section, 9-3, this hypothesis of internal, horizontal and temporal difference is again a valid question for empirical testing.

Although the horizontal excavation units are fairly straightforward, changes in the method of determining vertical distribution of artifacts during excavation prevents them from being consistent throughout the site and complicates analysis. Artificial 3" levels were used in the early work on segment 9-1. However, the conditions of the site made keeping these levels accurately nearly impossible, so 6" levels were adopted instead. In 9-2, some of the natural stratigraphy became more readily evident, and two natural layers were used. As the work progressed, these natural layers were subdivided into 3" artificial levels. Layer 1 had two, and in some places three levels; Layer 2 had only one. Some of 9-2 and much of 9-3 were dug using this scheme with 2 natural layers and one or more arbitrary levels.

Late in the 1966 season and toward the end of the work on 9-3, the natural layer system was again altered to include a third natural layer, and the artificial levels were dropped. Stratum 1 in this natural layer system included everything from just below the surface sod to 7" below the surface, Stratum 2 included everything from the base of Stratum 1 to 1' below the surface sod, and Stratum 3, extended from the base of Stratum 2 to sterile. Although certain aspects of the stratigraphy, such as the occurrence of a heavy organic layer in many parts of the site, offer some assistance, this complex system makes it difficult to determine whether the same physical position vertically means the same thing temporally in different portions of the site.

When excavation began in 1970, however, this natural layer system presented some difficulties. Where squares were partially excavated, and the point at which work had ceased was known, there were few problems. But as newer areas were opened up, particularly square 5L5, it became difficult to follow the natural stratigraphy. Therefore, for square 5L5 arbitrary levels which correspond with the depths given for the Strata were employed. These levels are believed to be very close to the natural Strata used in 1966 and for the purposes of this report the two systems have been equated.

This use of different schemes for reckoning vertical provenience causes serious difficulties in understanding the site, because it is hard to determine what a particular provenience means relative to other parts of the site. Early in the analysis, it became clear that there was no good way in which all the various systems could be equated. Therefore, a system which recognizes two levels in the 9-1 and 9-2 portions and three levels in the 9-3 portion seemed the most reasonable solution to the stratigraphy problem. Since the 9-1 and 9-2 portions of the site are not contiguous however, it did not seem prudent to combine the material from them for purposes of analysis. Therefore, the tests that follow in Chapter 5 compare the data from each of the seven segments of the site, that is, each level from each portion. This separation of the different segments should not be taken as implying there is no physical relationship between them, but instead as an attempt to take the most conservative course in analysis so that if the results are significant, their significance cannot be attributed to the effects of combining units.

SECTION II

THE EXPLANATORY SYSTEM

INTRODUCTION

This study argues that the best explanation for the long unchanging occupation of the Nanook Site followed by its abandonment is one based on first the presence and then the absence at the site location of at least one key resource necessary for subsistence. To initiate the explanation, it is necessary to define further some of the concepts used in the explanation, present the logical system, load the system with these concepts, and prepare for fitting the loaded system to the description.

As noted earlier, this study's approach to implementing the pattern model is drawn from the work of Rice (1975) and relies heavily on his presentation for its structure. Rice's data are drawn from the southwestern U.S. and are quite extensive. Therefore, he was able to construct a considerably more sophisticated set of interrelated concepts with which to load the system. Since the data for this research are quite limited (although rather extensive by arctic standards), the concepts used to load the system are considerably simpler. However, it is one of the strengths of the explanatory model used, that as better data become available, a more involved set of concepts can be used and the complexity and power of the explanation expanded.

DEFINITION OF CONCEPTS

Settlement pattern. A settlement pattern is the physical expression on the landscape, detectable by archaeological means, of the geographic and physiographic relationships among a group of contemporary settlements within a single culture (Winter, 1968:110; Rice, 1975:58).

Settlement system. A settlement system "is the set of strategies employed by people in a single cultural tradition in the organization and scheduling of activities over the landscape, especially those activities related to subsistence (Rice, 1975:95)." The nature and number of artifacts that remain provide a record of the performance of these activities. Thus, activity differences can be detected as differences in artifact types and frequencies (Rice, 1975:95-96). Where these activities involve animal resources, an additional record may be provided by faunal remains.

A settlement system may be defined on the basis of different scheduling and organization attributes, and on differences in technological capability. Scheduling refers to the temporal arrangement of the population to perform the different activities within the annual cycle. Organization refers to the synchronic spatial arrangement of the population during the performance of these activities (Rice, 1975:96). While as yet, little is known about the settlement system of which the Nanook Site inhabitants were a part, (for example, was it sedentary or a seasonal round?) the concept of a settlement system as a way of looking at the relationships between geographic locations and their exploitation by a human population is very basic to the explanation.

Because use of the landscape requires access to certain resources, the locations selected for occupation (here both the term "occupation" and the term "settlement" are used broadly to include any kind of prehistoric land use, not just habitation) are chosen to allow the efficient use of the resources exploited. In a region where the same resource strategy is used across a broad area, similar kinds of locations will be chosen for occupation, and these locations will appear to the archaeologist as the same segment of the settlement pattern. Thus in many instances, evidence of the settlement pattern may provide valuable information on the settlement system.

Site location. A site location is a specific geographic place on which a site is situated. A site location contrasts with a settlement location which is a class of landscape on which a particular segment of the settlement pattern is located. A single settlement location may not necessarily be contiguous and may include several specific site locations.

Subsistence system. A subsistence system is the annual round of activities involved in the procurement of food resources (Rice, 1975: 99). Traditionally subsistence systems have been characterized by the nature of the resources which are exploited; for example, an agricultural subsistence system is one which uses domesticated plant resources. However, Cleland (1966) and Dunnell (1972) have used alternative criteria for defining subsistence, designating such systems on the basis of the way in which available resources are used instead of the kind of resources exploited. Thus a focal adaptation (Cleland, 1966:42) or an intensive subsistence system (Dunnell, 1972:78) is one which places reliance on a single, or at most, a few resources. Both an agricultural system dependent on maize and a northern hunting system dependent primarily on caribou and fish might be considered focal or intensive subsistence systems. By contrast, a diffuse adaptation (Cleland, 1966: 44) or extensive subsistence system (Dunnell, 1972:78-79) makes use of a wide variety of resources without relying heavily on any particular one (Rice, 1975:99). Temperate zone hunter/gatherers relying on a variety of wild plants, nuts, berries, fish and game would typify the diffuse or extensive pattern.

These two kinds of subsistence systems have some additional characteristics which are of interest. Because a diffuse or extensive subsistence system is dependent on a variety of resources, the failure of one of them can be made up by greater reliance on others. This characteristic makes these kinds of systems very stable through time, and as Cleland points out, "pre-adapted" to change. On the other hand, since focal or intensive systems are dependent on only one or a few resources, factors which threaten a resource or decrease the efficiency of their harvest put the entire subsistence system in jeopardy.

While relatively little is known about the Dorset subsistence system the faunal analysis in this study reinforces our image of it as a focal system. The results of this study in concert with future research should provide more definitive information on the subsistence system. For the present, however, the concept of the subsistence system is important to the explanation because it emphasizes that having certain resources available at a sufficient level and being able to exploit them efficiently is basic to the successful operation of the subsistence system and the maintenance of the settlement system continuity.

THE LOGICAL SYSTEM AND THE LOADED SYSTEM

To begin the construction of the logical system, it is necessary to state the basic postulate of this research. That is, <u>the abandonment of the Nanook Site after a long period of unchanging occupation, occurred because one or more of the resources necessary for subsistence</u>

ceased to be available at a sufficient level at that site location. This general statement contains the basic elements required by the pattern model to construct an explanation. The resulting logical system will have two entailments: 1) under certain conditions (discussed below), one or more necessary resources will not be available at a sufficient level, and 2) the absence of such a resource will result in abandonment of the site location (Rice, 1975:101).

The specific pattern explanation employed in this study is based on a logical calculus devised by Rice (1975:108). The calculus has four variables and one rule governing the changes in the values of these variables. The first two variables (designated with arabic numbers) denote the settlement pattern with and without the Nanook Site location; the second two variables (designated by letters) denote the site location with and without one or more necessary resources. A schematic diagram illustrating the value changes in the system variables is shown in Figure 27. Each variable can have a presence value (indicated by a +) or an absence value (indicated by a -) but each variable must have a value in every state of the system (Rice, 1975:103).

	Initial State	Rule	Final State
Variable 1	+		-
Variable A	+	→	-
Variable 2	-		+
Variable B	-		+

	Meaningless States		Impossible States	
Variable 1	+	-	+	-
Variable A	-	+	-	+
Variable 2	+	-	-	+
Variable B	-	+	+	-

Figure 27. Basic variables of the logical calculus. Reprinted from Rice (1975:103,104).

Because the logical system is a closed system, it is necessary to calculate all its possible values, and to show that only one set of values can result from the operation of the logical calculus. Figure 27 shows these alternative states. All of these states are meaningless or logically impossible. For example, it is meaningless for a settlement pattern to both include and exclude occupation of the Nanook Site location, just as it is impossible for the site location to both have and not have a necessary resource. Likewise, it is logically impossible that the site would be part of the settlement pattern yet missing one or more of the necessary resources, or conversely have all the necessary resources, but be excluded from the settlement pattern.

Along with the variables, the logical calculus includes one or more rules. "A rule, or process, is a statement of the relationships which hold between a set of variables within a system, and relates a change in the value of one or more variables to the subsequent changes which occur in the value of the other variables" (Rice, 1975:105). The calculus in constructed so that only one kind of change can take place; the rule delineates the conditions for that change.

> Rule 1: If a site location can no longer supply one or more of the resources necessary for subsistence at a sufficient level, that location will no longer be used as a settlement site.

Since arctic populations exist in a highly sensitive ecosystem and are involved in a focal or intensive subsistence system, any factor which would remove a resource from the system or reduce the efficiency of resource harvesting would have an immediate effect. Such a factor would provide a strong impetus for a local group to search for a more optimal location.

THE LOGICAL CALCULUS

Given: Variable 1
Variable 2
Variable A
Variable B

Condition x, which includes some value c

By definition
Var (1) co-occurs only with Var (A)
Var (2) co-occurs only with Var (B)
Var (A) cannot co-occur with Var (B)

Rule 1: If condition x increases to c, where "c" is some constant value, then Var (A) will be replaced by Var (B).

Therefore: If condition x increases to c, Var (1) will be replaced by Var (2).

(Rice, 1975:108)

THE LOADED SYSTEM

V(1) - settlement pattern which includes occupation of the Nanook Site location
V(2) - settlement pattern which excludes occupation of the Nanook Site location
V(A) - presence at the Nanook Site location of all necessary resources
V(B) - absence at the Nanook Site location of one or more necessary resources.

Rule 1: If a site location can no longer supply one or more necessary resources at a level sufficient for subsistence, that location will no longer be used for the same segment of the settlement pattern.

PREPARATION FOR FITTING

Once the logical system has been loaded with the concepts, fitting the loaded system to the description can proceed. As noted in Chapter 2, Rice (1975) has made a major contribution to the scientific use of the Meehan System Paradigm by showing how to fit the system to the description efficiently through a set of hypothesis tests. This set of tests includes: 1) one hypothesis for the identification in the description of the system variables, 2) two hypotheses to demonstrate isomorphism between the loaded system and the description, and 3) three hypotheses related to the operation of the rule.

The first two sets of hypotheses should be self-explanatory. However, the third set deserves further comment. Three factors might serve as the missing resource. As indicated by the previous discussion of climatic change and animal resources, the decline in ringed seal and particularly caribou which would be expected with a warming climatic trend might represent the resource which is lacking. However, if the local physiographic conditions are sufficient to buffer the area against significant effects from climatic change, other more localized factors might enter in. The Nanook Site is located farther from the high tide line, which would have been contemporary with the site's occupation, than other sites in the Tanfield Valley. At one point the site may simply have become too far from the water for one or more important activities, such as those which might involve use of a boat, and the site location was abandoned for one more favorably situated. A third alternative relates to drainage of the site location. The configuration of the "pocket" in which the site is located is such that during the warmer months, water readily drains in, but less readily drains out. The accumulation of sod, bone and other refuse in the site location may have aggravated the situation. If a reasonably well-drained site was a requirement for the occupation, the site may well have been abandoned when drainage conditions deteriorated.

HYPOTHESES FOR FITTING THE LOADED SYSTEM TO THE DESCRIPTION

I. Hypothesis for the Identification of the System Variables

A. The Nanook Site is one location used periodically as the location for the same segment of the unknown local Dorset subsistence-settlement system.

Test Implications

1. The site is Dorset throughout.
2. The dating of the site is accurate.
3. Use of the site location is periodic.
4. Artifacts which can be shown to reflect primarily function should show little or no significant change in their types or proportions within different segments of the site.
5. Other area sites with contemporary dates and different locational parameters should contain different frequencies, and perhaps also different types of tools present.
6. Other area sites with contemporary dates and the same locational parameters should show very similar frequencies and types of tools.

II. Hypotheses to Demonstrate Isomorphism

A. The climatic change which took place during all but the very end of the period when the site was occupied was rather gradual and minor in magnitude. Therefore, until the very end of the period of site occupation, the availability of resource animals in the area was not significantly affected by climatic change.

Test Implications

1. Climatic data from the period during which the site was occupied shows that climatic change was gradual until the end of the period of site occupation.
2. The faunal remains from the site show a fairly uniform species and age structure throughout the different site segments.
3. Other sites with different locational parameters and occupied at the same time show different faunal characteristics.
4. Other sites with the same locational parameters and occupied at the same time show similar faunal characteristics.

B. Certain physiographic characteristics of the local environment can serve as a buffer against the effects of climatic change and random or cyclical variation in the availability of animal resource populations.

Test Implications

1. Data on the local environment should show evidence of the presence of such a potentially buffering geographic feature.
2. The faunal data from the site should show a greater consistency over time in the availability of those species affected by the buffer than of those species not affected by the buffer.

III. Hypotheses Related to the Operation of the Rule

A. Climatic change brought about the abandonment of the Nanook Site. One or more essential animal resources decreased as a result of this climatic change, and the former occupants selected other more suitable locations for their subsistence activities.

Test Implications

1. If the occupation of the Nanook Site ceased due to a decrease in animal resources brought on by climatic change, other sites in the Cape Tanfield sequence should show a similar sensitivity to climatic change.
2. Other sites in the same area with the same locational parameters and contemporary dates should also show signs of abandonment or a marked change in both the species and age structure of the faunal remains and the frequency of the artifact classes present.
3. Sites dating to the temporal period following the occupation of the Nanook Site will either not appear in the same kind of location as the Nanook Site, or if they do, they will have different species and age structure among their faunal remains and different relative frequencies of functional artifact types.

B. The activities carried on at the Nanook Site demanded proximity to the shoreline. During the 500-600 years of occupation, isostatic rebound caused the site to gradually become farther from the high tide line. At the time of site abandonment, the site had become too far from the water for one or more key activities carried on in this segment of the subsistence-settlement system.

Test Implications

1. Evidence from the site of warm weather activities connected with the harvesting of marine resources.
2. At least one site very similar to the Nanook Site in terms of tool frequencies and faunal remains should be found. This site should have basically the same locational parameters, except that it should be closer to the high tide level. The date of the initial occupation of this second site should correspond fairly closely to the final occupation of the Nanook Site.

C. The topography of the site location, combined with the accumulation of sod and refuse resulting from human occupation, made the site location wet and uncomfortable. Therefore the site's occupants moved to another location to escape these undesirable conditions.

Test Implications

1. Evidence of refuse accumulation and wet drainage conditions on the site location.
2. Evidence of site occupation during at least part of the year when the ground was not frozen completely.
3. At least one site very similar to the Nanook Site in terms of tool frequencies and faunal remains should be found. This site should have the same locational parameters, except that it should be situated where there is better natural drainage, or at least where there is no accumulation of debris and sod to cause drainage problems.

NOTES

1. Because all of these dates were taken from Radiocarbon, there should be uniformity with regard to half-life, meaning of the standard deviation, etc., as all dates reported in Radiocarbon conform to certain uniform reporting conventions.

2. A dispersion diagram presentation of radiocarbon dates has several other advantages (Ottaway, 1973). First, where large numbers of dates are involved, it makes display clearer and more economical. Second, the statistical model underlying the diagram, unlike the bar graph, does not over-emphasize extreme upper and lower values, and thereby distract attention from what is usually the bulk of the dates which do not exhibit extreme tendencies. Similarly the diagram is relatively insensitive to the addition of one or two subsequent observations. This means, for example that the later addition of an extreme date will not have a major impact on the presentation or interpretation of the information about the duration of a cultural entity in a compact form and make it easy to compare the duration of one entity with another. As such, it facilitates testing whether or not two entities overlap or can be considered to be samples drawn from the same population. Such a test can be performed using the Tables of the Hypergeometric (Four-way) Distribution (Seigal, 1956). Fourth and finally, the dispersion diagram technique avoids the pitfalls of averaging dates. That is, because the radiocarbon dates for an event of some duration do not fall into a predictable distribution, such as the normal distribution, a measure of central tendency such as an average will not necessarily provide useful information. Furthermore, averaging radiocarbon dates is not a useful technique for presenting dates which denote the duration of an event, as opposed to the occurrence of an event at a single point in time (Dekin, 1975; Ottaway, 1973; Waterbolk, 1971).

The most apparent disadvantage of the dispersion diagram technique is that it does not show the standard deviation of the individual dates, and therefore there is a fairly significant statistical probability that the limits of the bar graph are not accurately portrayed. Ottaway (1973) has countered this apparent weakness of the technique by asserting that archaeologists have an unrealistic image of the precision which radiocarbon dating can provide. She also shows that for the purposes for which dispersion diagrams are best suited, the technique already provides a good reflection of the uncertainties of the data, and that the extra information provided by the standard deviation is really not necessary.

3. Bryson (verbal communication) has noted the existence of some evidence which suggests that instead of a clearly warmer period, this episode may have merely been highly variable. While the evidence does, as a whole, point to the episode having a warmer character, it can be argued that for the purpose of this problem, a highly variable

climatic episode would create much the same effect on the resources utilized by human occupants of the Nanook Sites as a consistently warmer one. (p. 98)

4. Glacerization is a term used more frequently by British geologists. It denotes the formation of an extensive, but rather thin, ice sheet. The more familiar term, glaciation, is very similar, but tends to denote the formation of the more familiar forms of glaciers. (p. 108)

5. Additional information on ecology and resources, presented from the perspective of an archaeologist, is available in Dekin (1975). (p. 160)

6. Fasting and loss of the blubber layer also causes seals to sink much more readily when they are shot at this time of the year. (p. 164)

7. McLaren (1958a) describes an extreme case of this phenomenon. Eskimos hunting in open water in southern Andrew Gordon Bay and west of Cape Dorset find extremely small seals which appear to be starvelings, animals born inadvertently on moving ice, or perhaps in a shelter on an ice sheet which became separated from the fast ice shortly after the pups' birth. Probably as a result of this fact, more northerly areas where break-up comes later tend to produce a ringed seal population of larger overall size. (p. 166)

8. It is easy to see from the discussion of ringed seal habitat that the frequent existence of this lead would contribute significantly to the lower ringed seal index east of the site area along the coast. (p. 172)

CHAPTER 5

METHODS, TESTS, AND RESULTS

SECTION I

METHODS AND THEIR IMPLEMENTATION

PART I

RADIOCARBON DATING

INTRODUCTION

An accurate chronological framework is essential to the explanation of any problem involving change over time. Since radiocarbon dating is the basis for temporal control in this study of the Nanook Site archaeology, it is important to investigate the various sources of variability which might affect or modify that chronological framework. The dating of the site is most directly relevant to Test Implication I.A.2. which states that the radiocarbon chronology accurately reflects the temporal chronology of the site. The following discussion of the methods used to test this implication of Hypothesis I.A. will begin by examining these important sources of variability. A number of recent publications in both the radiocarbon and archaeological literature have dealt with this issue. Where appropriate, references will be made to these publications to shorten the discussion which follows. Those sources of variability which become uniquely significant in an arctic context (Campbell, 1965) will be discussed more thoroughly.

SOURCES OF VARIABILITY IN RADIOCARBON DATING

1. Strength of association with archaeological context. The issue

of association has not been given as much attention as it deserves, for it is basic to the accurate use of radiocarbon dates. The questions of "how good?" and "what kind?" must be dealt with frankly in any discussion of association, for the issues of the location of a sample with respect to other archaeological data, and whether the sample should provide a minimum, maximum or contemporaneous date are often ignored. The emphasis here on the question of association stems, in part, from the fact that arctic soils are subject to a number of frozen ground phenomena such as solifluction and the processes surrounding the occurrence of frost cracks, ice wedges, and patterned ground. Such processes may drastically alter the physical relationship between sample material and its archaeological context, a relationship which is all important if accurate dating is to take place (Waterbolk, 1971).

The period of time at which the sample was a living organism relative to the time at which the sample was buried is a related issue. For example, if the sample is grain or skin, the difference in these two time periods is probably negligible. However, if the sample is wood, the difference may be considerably greater (Waterbolk, 1971). This latter issue is particularly crucial in the arctic where wood (or wood charcoal) may be driftwood which could be a century or more old at the time of its burial.

2. Collection and handling of radiocarbon samples. Several authors have commented recently on the significant effect proper collection, handling and packaging of radiocarbon samples may have on the accuracy of results (Burleigh, 1974; Olsson, 1972; Polach and Golson, 1966; Ralph, 1971).

3. Contamination and pretreatment. The problem of the contamination of a sample with a younger source of carbon can significantly alter a radiocarbon date. Such contamination may be in the form of the penetration of rootlets, of humic acid from decaying plant material (Campbell, 1965), or of ground water or melt water carrying dissolved carbonates carrying "old" carbon (The "hard water effect") (Deevey et al., 1954) or other carboniferous substances in solution (see comments by Maxwell in Kogoshi et al., 1973:49). All three of these sources of contamination may affect arctic dates.

In some situations, the only remedy is a thoughtful choice of samples so that a contaminated sample is not submitted to the laboratory in the first place. However, the primary means of dealing with contamination problems is pretreatment (Burleigh, 1974; Olsson, 1972; Polach and Golson, 1966; Ralph, 1971) which for some time has involved primarily the physical removal of contaminants such as rootlets, and washing with HCl and sometimes NaOH (see, for example, Stuckenrath, 1965). More sophisticated forms of pretreatment are presently being developed for some materials (Burleigh, 1974), but the standards for pretreatment among laboratories are still far from uniform (Burleigh, 1974; Olsson, 1972).

In cases where contamination is suspected and the effectiveness of pretreatment is not clearly known, it is common practice to divide a sample into different fractions, date the different fractions and compare the results. If the dates for the different fractions are highly disparate, the date should be discarded due to clear evidence of sample contamination (Olsson, 1972; Waterbolk, 1971).

4. Laboratory techniques and standards. Once the sample is treated for contaminants and prepared for counting by conversion to a chemically standard form, one of two basic counting methods is used: proportional gas counting or liquid scintillation counting (Burleigh, 1974; Ralph, 1971). With the perfection of the devices and techniques involved, dating precision has increased until, for example, with the proper pretreatment and preparation and with sufficient counting time, the standard deviation of some dates can be reduced to as little as $\pm$12 years (Stuiver, verbal communication). This increased precision has important implications since variation in radiocarbon dates can arise because different laboratories (or the same laboratory at different times) may use different techniques and equipment and may have different standards of accuracy.

The issue of interlaboratory differences is not one to which investigators have addressed themselves very willingly. Some preliminary steps have been taken to try to detect these differences (e.g. two laboratories dating two parts of the same sample of known age), and some further steps have been urged (Clark and Renfrew, 1973; Renfrew and Clark, 1974; and others). However, information to help the archaeologist or geologist deal more intelligently with this source of variation is not yet available.

5. Half-life estimate. The issue of the most accurate half-life estimate for Carbon-14 has not yet been resolved (Olsson, 1972; Ralph, 1971). While 5730$\pm$40 is considered the most accurate estimate currently available, the earlier "Libby half-life" of 5568$\pm$30 (often rounded to 5570) is generally used by convention so that dates formulated before and after the more recent estimate was made known are based on the same

half-life. Dates reported in Radiocarbon observe this convention, but whatever the source of the dates, it is important for comparability that they all be based on the same half-life estimate. Dates calculated on the basis of the 5570 half-life estimate may be converted to a date based on the 5730 half-life estimate by multiplying the date by 1.0287 (Olsson, 1972) or 1.03 (Burleigh, 1974; Ralph, 1971).

6. Fractionation. Fractionation is a process in which the tissues and organisms of the original sample materials take up the various carbon isotopes in other than the expected proportions. One of the major problems with dates from arctic sites is that some of the more frequently encountered sample materials such as antler (Rainey and Ralph, 1959; Ralph and Ackerman, 1961), ivory, sod, baleen, and charred animal fat, probably seal fat, (Dekin, 1975; Harp, 1971; Stuckenrath, 1971; McGhee and Tuck, 1973) produce dates which are often aberrant. The reasons for such aberrant dates are not completely known, but it is now suspected that fractionation affects some, if not all, of these materials.

The most frequent case of fractionation involves the absorption of less than the normal amount of Carbon-14, so that the apparent age of the resulting sample is abnormally old. The proportion of Carbon-13 to Carbon-14 in living tissue is constant. The normal ratio of Carbon-12 to Carbon-13 is also known. By using mass spectroscopy to measure the Carbon-13/Carbon-12 ratio in a radiocarbon sample, and by calculating how that ratio differs from the normal ratio, the degree of fractionation can be discovered (Burleigh, 1974; Mangerud, 1972; Olsson, 1972; Olsson and Osadebe, 1974; Polach and Golson, 1966; Ralph, 1971; Renfrew and Clark, 1974), and a correction can be applied.[1]

Until quite recently, fractionation was considered a problem with only a few materials such as shell (Ralph and Michael, 1967; Polach and Golson, 1966; Mangerud, 1972; Mangerud and Gilliksen, 1975), so that relatively few Carbon-13 determinations were made on Carbon-14 samples. Many laboratories merely estimated any correction or applied none at all. As evidence accumulates that more materials, including corn and various other grasses (Bender, 1968; Lowdon, 1969), and fats (Struckenrath, 1971) may be subject to fractionation, the problem is receiving greater attention, and laboratories are testing for Carbon-13 on a more regular basis. Unlike some of the factors which will be discussed subsequently, the problem of franctionation is thoroughly amenable to solution. The technology is available and the natural processes involved are becoming more clearly understood. It remains mainly for the questionable materials to be tested under the proper conditions.

7. Variation over time in the proportion of Carbon-14 in the atmosphere. When Libby first developed the Carbon-14 dating method, he assumed that the amount of Carbon-14 in the atmosphere had not changed over time. This basic assumption of the method was first questioned 15 years ago when de Vries (1958) detected changes which he hypothesized were related to climatic change. Since the first detection of the "de Vries effect", considerable effort has been expended to establish the nature of the processes involved in the variation of atmospheric Carbon-14. The issue centers around variation in cosmic rays entering the earth's atmosphere, since it is cosmic rays which continually replenish the earth's supply of Carbon-14 (Ralph and Michael, 1967). Recent research has suggested three causes for variation in cosmic ray bombardment (Damon, 1970; Stuiver and Suess, 1966; Suess, 1970). The

primary cause, which seems to account for at least half of the variability, is past changes in the geomagnetic moment of the earth (Bucha, 1970). A secondary cause which can be related at least to recent variations in Carbon-14 (during the 1500's and 1700's) is heliomagnetic variation; while a tertiary cause appears somehow related to climatic change. In this latter case, Mangerud (1972) has articulated a mechanism involving the oceanic circulation of Carbon-14 whereby the influence of climatic change might make itself felt.

In conjunction with their attempts to discover the causes of Carbon-14 variation over time, investigators interested in this problem have also tried to measure the magnitude of the variation of radiocarbon dates relative to calendrical dates using dendrochronology. An 8,000 year tree ring chronology based primarily on bristlecone pine was developed by Ferguson and his colleagues (Ferguson, 1968; 1970; 1972) at the University of Arizona Tree Ring Laboratory. Three radiocarbon laboratories, at the University of Pennsylvania, the University of Arizona, and La Jolla, have been primarily involved in dating the wood segments of known age supplied by the Arizona Tree Ring Laboratory. The result is a large series of radiocarbon dates (over 600) against which the tree ring chronology can be matched.

Originally it was hoped there would be agreement on one standard correction curve, but the principal investigators from the three laboratories have not been able to agree on a single curve and have published their own correction curves (Damon _et al_., 1972; Damon _et al_., 1974; Michael and Ralph, 1972; Ralph, Michael, and Han, 1973; Suess, 1970). These curves agree well on the major, as well as some of the minor trends; however, at some points in time when there appear to have been rapid fluctuations in the proportions of Carbon-14 in the atmosphere, there are "kinks" in the curve on which these researchers cannot agree. In addition to these three curves, at least three other workers (Renfrew and Clark, 1974; Switsur, 1973; Wendland and Donley, 1971) have produced calibration schemes based on the research of the original investigators.

Renfrew and Clark (1974) have provided thoughtful criticism on the various correction schemes. However, their comments and approach seem to be directed toward a level of precision which is not practical or relevant here given the other factors which influence the Nanook site dates. The corrections which the various schemes provide for the Nanook dates do not differ markedly (see Table 10), and the differences which so arise are generally not much greater than the uncertainties which grow out of the statistical error inherent in any date combined with other factors, such as the problems associated with the nature of the sample materials. Therefore, the contrasts among these different approaches to calibration do not warrant discussion at this point.

The variation in atmospheric Carbon-14 discussed above might well be considered to be "natural" variations. Human activities have also contributed to atmospheric Carbon-14 variation. The advent of atomic testing added large quantities of Carbon-14 to the atmosphere (Munnick and Roether, 1967). Even before atomic testing began, the intensive burning of fossil fuels added a large quantity of very old or "dead" carbon to the atmosphere ("Suess effect") (Suess, 1955). Fortunately, corrections for both of these sources of variation are available (Houtermans _et al._, 1967).

8. Rates of reservoir exchange. To this point, the discussion has focused on Carbon-14 sample materials which drew primarily on the atmospheric or terrestrial carbon reservoirs during their lifetime. However, many of the sample materials found in arctic sites, such as ivory, baleen, whale bone, and charred seal fat, come from animals which draw the major part of their sustenance from the marine carbon reservoir.

The marine carbon reservoir differs from the atmospheric or terrestrial reservoirs in that there is no rapid and complete mixing of the new Carbon-14 continuously being generated in the upper atmosphere with the existing carbon supply. Interchange between the surface layers of the ocean and atmosphere is relatively rapid. But the rate of exchange between surface layers and lower ocean layers is often much slower. Different water masses within the ocean have different "apparent ages" which may range from as little as 200 years to as much as 2500 years older than dates on contemporary materials from the atmospheric or terrestrial reservoir, depending on local circumstances. Organisms in these subsurface layers yield a greater age than expected when radio-carbon dated because the proportion of Carbon-14 in their environment is depleted. Olsson (1972) and Mangerud (1972) have explained this phenomena in greater detail.

Another form of reservoir exchange which may enhance this tendency for water bodies within the oceanic reservoir to exhibit "apparent age" is the movement of "old" carbon from the terrestrial reservoir into the marine reservoir. This transfer may come about when old carbonates weather out of carbonate rocks along the shoreline (Dekin, 1975). It may also occur where ground water or glacial ice enter the ocean at some depth without coming into contact with the atmosphere (Mangerud, 1972).

In either case, such phenomena are relatively localized and the circumstances leading to their occurrence can usually be recognized.

Efforts to identify and date the apparent age of various bodies of water began about 15 years ago with the work of Broecker and his colleagues (1960) in the Atlantic. They found that between 40°N and 40°S longitude, there existed a stable surface layer with little variation in its apparent age (320-520 years). Since then work has continued in the Pacific, Antarctic and elsewhere. Some of the most recent work by Olsson (1972) and by Mangerud (1972; Mangerud and Gilliksen, 1975) has investigated the apparent age of Scandinavian waters by the careful radiocarbon dating of shells collected prior to atomic testing and prior to the advent of a sizeable Suess effect. This technique has proven successful because it has been shown that the isotopic composition of marine shells is close to being in equilibrium with the surrounding water. The dates which have been accumulated show that waters off the coast of Norway which have a composition relatively similar to that in Hudson Strait, have an apparent age averaging 440 years.

The waters which Mangerud and his colleague tested consist of a mixture of Atlantic and Arctic waters with some water from the less saline Baltic Sea. The waters of Hudson Strait off the south coast of Baffin Island consist of a very similar mixture: Arctic water draining out Hudson Strait from the rest of the Canadian archipelago, Atlantic water which, as an arm of the Atlantic current, sweeps into Hudson Strait along the south coast of Baffin Island turning south near Big Island and sweeping out again along the northern coast of the Ungava Peninsula, and a small quantity of less saline water from Hudson Bay (see Figures 20 & 22 showing ocean currents). On the basis of this parallel in the composition of the respective water bodies involved, a reasonable case can be made for an adjustment for apparent age of around 400 years for radiocarbon dates from the south coast area. This adjustment agrees well with that given by Olsson (1972; Olsson and Osadebe, 1974) for whale bone from Kapp Linne, Spitsbergen, and for several other datings, primarily of marine shell. The problem of differences in reservoir exchange may well be solved by extending research such as Mangerud and his colleagues are conducting to a broader geographic area.[2,3]

9. Changes in oceanic circulation. Although the problem of reservoir exchange seems solvable, there is one further complicating factor: change in oceanic circulation. If the known water masses remained stable over time, the approach used by Mangerud and others could provide a correction constant for various geographic areas. However, if these water masses change their position and hence their reservoir exchange relationships, their apparent age will also change over time. Since it is known that shifts in currents do occur with climatic change, this variable should be considered. Such changes have a further implication which McGhee and Tuck (1973) point out. Changes in oceanic circulation mean that applying any calibration curve to data from the oceanic reservoir may be quite difficult because the relationship between Carbon-14 variations in the ocean and the atmosphere will be complex and perhaps not clearly related.

This problem is probably not as serious as it might seem, however. Mangerud and Gilliksen (1975) recognize the issue, but argue that climatic changes of a magnitude necessary for current shifts which would seriously affect reservoir exchange, and hence apparent age, would come about only during periods of major glacial advance and retreat. The last such event at the end of the Wisconsin was sufficiently long ago that the statistical error of a date from that period would be greater than any error which could be incurred by changes in circulation patterns. Thus all dates on archaeological sites in the arctic are probably too recent to be seriously affected by this problem.

Tests

Test I.A.2.

This Test Implication maintains that the dating of the site is accurate. Yet the impact of examining these nine sources of variability in radiocarbon dating is to cast some suspicion on the Nanook Site dates. If, for example, some of the dates are invalid or inaccurate, in particular, if the dates at the early or late end of the site's chronology appear weak or internally contradictory, the occupation of the site may have been considerably shorter than originally supposed. If this was the case and the site was occupied for a fairly short period of time, it would be very difficult to detect either change or stability, especially in an area where change occurs very slowly.

Implementation. Test Implication I.A.2. will be tested by applying those corrections which are appropriate for the various sources of variability, by plotting the alternative dates for the various factors, and deciding if the initial chronology based on the raw dates is reasonably sound.

PART 2

FAUNAL ANALYSIS

INTRODUCTION

The eastern arctic is an area where the plant resources available for human exploitation are meager at best. Therefore, a very large portion of the basic subsistence needs of any prehistoric human population in this area for food, clothing, and even housing are supplied by the animal resources. The faunal remains left by these animal resources are an extremely important source of data for this research in which hypotheses concerning resource change are basic to the problem. The analysis of these faunal remains will be presented in three different parts of the dissertation. The methods and their implementation will be presented in this first Section of Chapter 5. Tests involving faunal analysis will be considered along with the results of the tests involving other methods in the second Section of Chapter 5. Finally, additional data derived from faunal analysis which are of interest, but which are not as directly relevant to the hypotheses being tested in the dissertation, are found in the Site Report Appendix.

In order to better visualize how the results of the faunal analysis will be used to help test hypotheses, it may be useful to refer from time to time to Table 4 which shows the hypotheses, test implications, tests, and data for which faunal information is relevant. To briefly summarize from Table 4, the faunal analysis is expected to provide evidence of the following: 1) a uniform species structure from the earliest to the latest part of the site, 2) a uniform age structure in

Table 4. Hypotheses, Test Implications, Tests and Data used in Faunal Analysis.

Hypotheses	Test Implications with Tests Requiring faunal data	Tests	Faunal data required
I. Hypotheses for the Identification of the System Variables			
H.I.A. The Nanook Site is one location used over a period of approximately 500 years as the location for the same segment of the unknown local Dorset subsistence-settlement system	T.I. I.A.4. Artifact units, which can be shown to reflect primarily function, should show little or no significant change in their proportions from earlier to later segments of the site.	T. I.A.4. The percentage frequency of functional class members should be the same or very similar in all the segments of the site.	
		Test of units (1) for T.I.A.4. Since the artifacts which are members of these functional classes are used to garner and process animal resources, similar patterns of faunal remains should occur in segments of the site with similar patterns of occurrence of functional artifact types.	Results of Tests II.A.2.a. & b.
II. Hypotheses to Demonstrate Isomorphism			
H.II.A. The climatic change which took place at the end of the period when the site was occupied was rather gradual and minor in magnitude. Therefore, until the very end of the period of site occupation, the availability of resource animals in the area was not significantly affected by climatic change.	T.I. II.A.2. The faunal remains from the site show a fairly uniform species and age structure from the earliest to the latest levels of the site.	T. II.A.2.a. The faunal sample from each level of the site should have very similar proportions of the same species represented.	Counts of elements for each species category from each level.
		T. II.A.2.b. The faunal sample from each level should show similar proportions of different age cohorts of caribou and phocid seals.	1) Counts of mandibles classed by size, tooth wear, and tooth eruption for *R. tarandus*. Counts of mandibles classed by size and rugosity for *P. hispida* from each level. 2) The ratio of fused to unfused epiphyses for the six major long bones of the phocid seals from each level.
	T.I. II.A.4. Other sites with the same locational parameters and occupied at the same time show similar faunal characteristics	T. II.A.4. The faunal sample from other sites with the same locational parameters and the same dates should have similar proportions of the same species as the Nanook Site faunal samples.	Counts of elements for each species in the faunal remains from the Morrison Site.
H.II.B. Certain physiographic characteristics of the local environment can serve as a buffer against the effects of climatic change and random or cyclical variation in the availability of animal resource populations.	T.I. II.B.2. The faunal data from the site should show greater consistency over time in the availability of those species not affected by the buffer.	T. II.B.2. There should be greater variability from the earliest to the latest part of the site in the faunal remains of land mammals than in the faunal remains from sea mammals.	Counts of elements for both caribou and phocid seals from each level.

Table 4. (cont.)

Tests	Faunal Data Required	III. Hypotheses Related to the Operation of the Rule	Test Implications with Tests Requiring faunal data
T. III.A.1. The entire southern Baffin Island sequence should show sensitivity to climatic change.		H.III.A. If the occupation of the Nanook Site ceased due to a decrease in animal resource brought on by climatic change, other sites in the Cape Tanfield sequence should show a similar sensitivity to climatic change.	T.I. III.A.1. Climatic change brought about the abandonment of the Nanook Site location. One or more essential animal resources decreased as a result of climatic change, and the occupants selected another more suitable location for their subsistence activities.
Test of units (1) for T. III.A.1. Same as Test of units (1) for T.I.A.4. above.	The same data as Test T. III.A.2. a. & b. above.		
T. III.B.1.a. Presence of a marine-oriented faunal species which could only be taken during that part of the warm weather season when it was possible to use a boat.	Evidence of one or more migratory bird species which would have been present only during the open water season.	H.III.B. The activities carried on at the Nanook Site demanded proximity to the shore-line. During the 500-600 years of occupation, isostatic recound caused the site to gradually become farther from the high tide line. At the time the site location was abandoned, the site had become to far from the water for one or more key activities carried on by this segment of the subsistence-settlement system.	T.I. III.B.1. There should be evidence from the site of warm weather activities connected with the harvest of marine resources.
T. III.B.2.b. The age structure of one or more species among the faunal remains is similar to what would be expected for the open water season of the year.	Counts of mandibles classed into three categories by age for P. hispida for all segments of the site.		
T. III.C.2.a. Same as T. III.B.1.a.		H.III.C. The topography of the site location combined with the accumulation of sod and refuse resulting from human occupation, made the site location wet and uncomfortable. Therefore the site's occupants moved to another location to escape these undesire-able conditions.	T.I. III.C.2. There should be evidence of occupation of the site during at least part of the year when the ground is not frozen.
T. III.C.2.b. Same as T. III.B.1.b.			

the major species exploited from the earliest to the latest part of the site, 3) greater consistency over time in the availability of marine mammal resources than of land mammal resources, 4) confirmation of the essentially functional nature of the artifact units employed to show: a) that there is functional continuity from the earliest to the latest parts of the site and, b) that all the sites in the southern Baffin Island sequence are sensitive to climatic change, 5) the occurrence of marine-oriented fauna which would have been present only during the warm weather months, and 6) an age structure in the major species exploited similar to that which would be expected to occur primarily during the open water season.

While the discussion is focused on what information is being sought from the faunal remains, it is useful to state explicitly what information is not being sought. Numerous recent analyses of faunal remains from archaeological sites (for example, Munson et al., 1971) have attempted to reconstruct the total amount of meat represented by the remains, or the dietary ration, the proportion of the total amount of meat comprised by each species identified. Such information has not been sought in this research because it is not relevant to the problem, and because the identified sample from the Nanook Site is such a small proportion of the total faunal material that such information would not be very meaningful (see section on Faunal Remains in the Site Report Appendix for additional discussion of these issues).

A number of processes affect the results of faunal analysis. Before the methods employed in this part of the research are described, it would be helpful to discuss at least some of these processes, since they may serve as sources of bias which affect various methods of analysis in different ways. One useful framework for discussing these processes is that put forward by Schiffer (1972) and discussed further by Schiffer and Rathje (1973). This framework is based on two classes of transformation process concepts: c-transforms, cultural transformation process concepts, which allow the archaeologist to explain "the spatial, quantitative and associational attributes of archaeological materials as a function of the depositional behavior of the cultural system that produced them (Schiffer and Rathje, 1973:170)," and n-transforms, non-cultural transformation process concepts, which allow "the archaeologist to explain and predict the interactions through time between a culturally deposited assemblage and the specific environmental conditions in which it was deposited (Schiffer and Rathje, 1973:170)."

> The use of both concept sets allows the archaeologist to mediate between the archaeological context -- the present -- and the systematic context -- the past behavioral system -- of the materials under investigation.
> (Schiffer and Rathje, 1973:170)

The rationale which Schiffer and Rathje offer for using such concepts is to bring consistency and explicitness to the use of transformation process concepts, so that they are accessible for discussion and testing. Yet, if this is their goal, they fail to recognize the need for a third set of transformation process concepts, namely, i-transforms, investigator transformation process concepts. These allow the archaeologist to explain the aspects of his or her analysis which result from the interaction between a particular archaeologist (or archaeologists) with his or her particular abilities, controlling models, and so on, and the data. In fact, the very use of a conceptual scheme employing n-, c-, and i-transforms might itself be considered an i-transform.

In order to understand more clearly why it is necessary to consider the role of n-, c-, and i-transforms, it is helpful to look at a set of ideal conditions for faunal analysis. These conditions never have and never will exist in any archaeological site. Yet in the course of using several of the methods which will be discussed below, one and sometimes several of these ideal conditions will be assumed to exist. Table 5 presents some of these ideal conditions as well as examples of the various kinds of n-, c-, and i- transforms which might be expected to affect them.

As in most current research involving faunal remains, two kinds of activities are involved in obtaining the information which such data can supply: identification and analysis. In this section the methods chosen, the rationale for their choice, and the details of their implementation are presented.

Table 5. Ideal Conditions for Faunal Analysis.

IDEAL CONDITIONS	PROCESSES WHICH ALTER THESE CONDITIONS -- EXAMPLES.
	c-transforms
1. All animals represented in the faunal sample are killed for human food.	-Keeping animals for traction, milking, hunting aids, pets, etc. -Hunting animals primarily for their skin or other non-food products or for dog food
2. All elements of all species are brought back to the site and none are subsequently removed.	-Constructing curated bone tools which are taken when the maker travels elsewhere -Butchering a large animal so far from the site that its size and the available means of transport prevent its movement to the site -Culturally conditioned food preferences
3. All bones of all animals are treated identically. If any bone is broken, only one fragment, clearly identifiable, survives.	-Cooking practices, for example the extraction of marrow from some bones of some species -Butchering practices -Preference for certain bones for tool-making
4. No meat is eaten at the site for which the bones are not present.	-Caching meat outside the site -Meat preparation practices such as drying in which the meat may be removed from the bones far from the site, processed and brought to the site for later consumption
5. All bones are distributed homogeneously over the site.	-Patterns of food distribution -Patterns of internal settlement spatial organization
	n-transforms -Dogs, foxes, wolves, or other scavengers selectively remove or destroy certain bones
6. All elements of all species are equally well-preserved	-Activities of scavengers as noted above -Differential soil deposition -Spacial differences in the degree of erosion -Differences in the effects of permafrost between the active layer and the frozen layer

Table 5. (cont'd.)

IDEAL CONDITIONS	PROCESSES WHICH ALTER THESE CONDITIONS -- EXAMPLES.
	i-transforms
7. The site is adequately sampled.	-Conditions such as permafrost or heavy vegetational cover prevent access to some parts of the site -Investigator lacks knowledge of sampling methods
8. All species and all elements are equally well recovered.	-Size of screens used too large to catch smaller bones -Differences in excavator perception and experience -Differences in investigators' definitions of an artifact
9. All species and elements recovered appear in the data to be analyzed.	-Breakage -Loss in transport or storage -Loss of provenience data
10. All elements and species have an equal chance of being counted, identified and analyzed.	-Differences in the skill of different identifiers -Contextual differences which make a bone or fragment more easily identified in one situation than in another -Differences in the kinds of units and paradigms used by different investigators

IDENTIFICATION

Methods

The specific steps involved in determining the animal species from which a bone or fragment comes have been detailed fairly well in a number of recent publications on faunal analysis (Chaplin, 1971; Gilbert, 1973; Olsen, 1971), so that it is not necessary to repeat them here. For many years, identification was the only step involved in faunal analysis, and in many cases all that was published was a list of the species found; often counts of the number of bones from each species were not even given.

A species list can provide useful information. From such a list it may be possible to find an indication of local environmental change, clues to larger-scale climatic change, or even evidence of long-distance trade. The presence of certain species which are found at a site location during only limited times of the year can also provide valuable information on the season or seasons when the site was occupied.

However, when the analysis of faunal remains is limited to producing a species list, much of the information to be gained from faunal research goes untapped. In current practice, identification is not limited to a species list and perhaps counts. Often the specific skeletal element, the side (right or left) from which it comes, whether its epiphyses are fused, and its degree of fragmentation are also recorded. For this study, all of these kinds of information were sought.

In addition to seeking the kinds of information listed above, this investigation also attempted to determine the age pattern of the animals represented in the faunal sample. Several techniques are available for this procedure: three were originally proposed for this project. The

first aging method involved constructing classes based on mandible size and tooth wear to determine at least the relative age of various specimens (Severinghaus, 1949; Ryel *et al.*, 1961). Initially this method was proposed for use only with caribou specimens, but later when more extensive reference material became available, it was extended to the phocid seals as well. The second aging method involved sectioning teeth to count the annual layers in the dentine (McLaren, 1958a; Smith, 1973). Seal teeth were the primary target for this approach. The third method involved determining the proportion of fused to unfused epiphyses among both the phocid seals and the caribou.

The Faunal Samples

The faunal material considered in this analysis includes bird and mammal bones from five different provenience units in two separate sites. These samples are briefly described below.

The 1966 Sample from square -15L15 in KDDQ 9. During the 1966 field season, a faunal sample was taken from one quarter of square -15L15 in the 9-2 section of the site. The sample was collected as a single unit with no separation of material from different levels. This initial sample was identified by Peter Murray and reported in an unpublished paper in 1967 (Murray, n.d.). Murray's paper provided some of the first information available on the nature of the fauna in any of the Cape Tanfield sites. While Murray had a strong background in zoology and his identification skills were good, his paper has some weaknesses in method which make the results he reports less valuable than they might be.

First, he failed to report the total sample size; there is no way to determine either the absolute number of bones in his sample or what proportion of the sample he was not able to identify.

Second, he did not recognize what he could and could not identify with surety. Almost all the phocid material in Murray's sample is identified as ringed seal, *Phoca hispida*, and his determinations are probably 98% current. Yet, the harbour seal, *Phocâ vitulina*, and the harp or Greenland seal, *Phoca groenlandica*, as well as the ringed seal, are found in the area today. Some skeletal elements from these species are not clearly distinguishable. When Murray made the identifications, he had available to him only one ringed seal skeleton, possibly a harp seal skeleton, but no comparative material for harbour seal. Thus, his comparative material was too limited for the degree of certainty he attempted in his identifications.

Third, he similarly failed to recognize the limits of his ability to identify certain elements as to species. Caudal vertebrae, vertebral fragments, ribs, and rib fragments, sesmoid bones and phalanges, are among the elements which can often be difficult to assign to a particular species. Murray's paper provides no clue as to how he handled these doubtful items.

Finally, he did not report how he dealt with material which was so broken or eroded that it could not be assigned to a given species, but could be identified at some higher taxonomic level (for example, material which was clearly from a seal, but from what species could not be determined). Because of these problems with Murray's report, his data is of no value for the kind of tests conducted for this research. However, the avifauna from this sample, a total of 580 bones, has been identified by the author, and the results are used for those tests requiring avifaunal data.

The 1970 Sample from square 5L5 in KDDQ 9. During the course of excavation in 1970, all the faunal remains from one five foot square were excavated and saved by levels. This sample constitutes the only faunal sample for the site with any form of temporal control. It includes a total of 7724 bird and mammal bones and is used for testing hypotheses involving change over time.

The 1970 Sample from other KDDQ 9 proveniences. The 1970 excavations involved digging drainage ditches to remove water from the site, and completing the excavation of a number of squares and balks which were left at the end of the 1966 season and which had begun to collapse. Because most of these units were in poor condition, it was not possible to maintain vertical control of this material. It comes from all three sections of the site, and for most purposes it has been lumped together by section; this sample numbers 11,961 bird and mammal bones.

The 1967 Sample from KDDQ 7-3 (The Morrison Site). The Morrison Site is a Dorset Site in the Cape Tanfield Valley located about 100 feet from the Nanook Site with some contemporary radiocarbon dates (Maxwell, personal communication). During the 1967 season, a sample made up of all the faunal material from one five foot square was collected without vertical control. All the bird and mammal bones from this sample, a total of 4595 specimens, have been identified, and for the purposes of some tests, it will be useful to compare this sample with the others from the Nanook Site.

Implementation

Part of the faunal material collected in 1970 (about 8000 specimens) was identified in the field; the rest in the laboratory at the Michigan

State University Museum and the University of Michigan Musem of Zoology. Field identification, while less than ideal in many respects, was necessary since the bulk of the bone recovered could not be transported from the site due to logistic limitations.

To aid field identification, notes and sketches of the major species expected were made prior to departure. On a few occasions, Inuit informants provided some assistance. In so far as possible, field identifications were biased toward conservatism. Any element which would not be identified with surety was brought back to the laboratory. Only mammals were identified in the field; all avifauna was brought back since it constituted a small, lightweight portion of the material.

For purposes of identification in the laboratory, the skeletal collections of the Michigan State University Museum's Zoology division were supplemented by additional materials borrowed from the American Museum of Natural History, the Smithsonian Institution, and from the Harvard University Museum of Comparative Anatomy. The identification of the mammals was aided by the assistance and advice of Elizabeth Butch Cardinal, a specialist in ethnozoology, Dr. Charles Cleland, Curator of Archaeology and also a specialist in ethnozoology, and Dr. Roland Baker, Curator of Zoology and Director of the Michigan State University Museum. The avifauna was identified using primarily the extensive reference collections of the University of Michigan Museum of Zoology. Here again the assistance of Ms. Cardinal, as well as the advice of Dr. Storer and several other members of the University of Michigan Museum staff was very helpful. The raw data derived from the faunal analysis is given in the Site Report Appendix.

Identifying the faunal material from Cape Tanfield involved some problems which are common to faunal analysis. Since procedures for dealing with these problems are not necessarily uniform (Lawrence, 1971), some explicit discussion of how they have been handled is in order. The first of these problems is that of distinguishing very similar species. Archaeologists working in the Near East face this problem with sheep and goats; the arctic specialist encounters a similar difficulty with phocid seals. As mentioned earlier, at least three small-to-medium-sized phocids are found in the Cape Tanfield area: the smallest, *Phoca hispida*, the ringed seal, is clearly far more common than the other two slightly larger species, *Phoco vitulina*, the harbour seal, and *Phoca groenlandica*, the harp or Greenland seal. Some elements of these species, such as the mandible, are clearly distinguishable, while others are not.

Ideally, as many fragments as possible should have been distinguished (Lawrence, 1971). However, since part of the analysis had to be done in the field where extensive comparative material was not available, it seemed wise to lump all three species in one category, labeled *Phoca* sp., and for most purposes, treat this category as a single species. It is believed that a very high percentage of the fragments, probably at least 95%, are ringed seal. This opinion is based on the fact that all identifiable mandibles are ringed seal and that the behavior of the other two species makes them much less likely to be found in the area.

A second common problem involves those skeletal elements which are often difficult to identify. Among the seals, these elements include some vertebrae, vertebral fragments, ribs and rib fragments, and sesmoid bones. Under the conditions of field identification, uncertainty also exists regarding metapodials and phalanges. Hence, all of these bones and fragments of these elements are among the most common, this designation greatly swells the "seal unidentified" category.

A similar situation exists among the small mammals where most of these same elements were lumped in the category "small mammal unidentified". However, since only three species and many fewer bones or fragments are involved, the effect is not as great. With caribou, the situation is quite different. For this species, such elements are quite distinctive, in part because there is only one large land mammal represented in the sample. Thus for caribou, these elements could be identified to the species level.

Differences in the way these elements are treated for different species can pose a comparability problem. In the section below on Analysis, two different approaches to the use of faunal data will be discussed. For one of these approaches, that using Direct Measures of the bones and fragments found, such lack of comparability does not cause problems, as long as the procedure used is uniform for all units from which faunal material is drawn. However, for the other approach, that using Inferred Measures of such information as numbers of individuals, meat weights and so on, such comparability is important. Therefore, when methods requiring Inferred Measures are used, only bones from those elements which are equally identifiable for all species will be used so that the data base is comparable.

Of the three methods proposed for aging, two proved quite useful but one turned out to be impractical. The method which proved unfeasible was tooth sectioning. The teeth of the bearded seal, Erignathus barbatus, wear down to almost nothing in the adult, and indeed the bone of the mandible was beginning to grow over the tooth sockets in some of the examples used for comparative purposes. The teeth from the phocid seals were too fragile for decalcification (Pyfer n.d.; Saxon and Higham, 1969), and the petrographic procedure for imbedding and cutting the teeth was too expensive and time-consuming to be practical, especially when useful, satisfactory age data could be derived by the other two methods. Problems of sampling error and independence also entered into the decision not to embark on tooth sectioning. In comparison with the appendicular skeleton, for example, relatively few jaw fragments are preserved. Thus, there is a small sample size for this element and some chance of sampling error. At the same time each jaw or jaw fragment produces several teeth which are not independent as indicators of age.

A more useful alternative method for aging seal was the method also used for caribou: comparison with a collection of specimens of known age. While this method is subject to sampling error, the problem is not multiplied by using several teeth from the same jaw. The comparative material for seals was supplied by Dr. Murray Johnson, Professor of Biology, and the Museum of Zoology at the University of Puget Sound, Tacoma, Washington. On the basis of criteria derived from this collection, all ringed seal or Phoca hispida mandibles (all Phocid mandibles came from this species) and bearded seal or Erignathus barbatus mandibles were placed in classes which in turn, could be categorized by age as 1) young of the year, 2) immature or adolescent (younger than age of sexual maturity), or 3) adult. Since the teeth of Phocid seals erupt very early, age determination of seal mandibles is based primarily on the overall size and rugosity of the mandible rather than tooth eruption. As indicated above, tooth condition also plays a large part in age determination for the bearded seal.

However, for age determination in caribou, tooth eruption and wear are of primary importance. The caribou teeth and mandibles were aged by Ms. Cardinal. Since no comparative material for caribou was available, the specimens were classified on the basis of criteria drawn from Michigan White Tailed Deer, *Odocoileus virginianus*, as comparative material for this species was plentiful. Because *R. tarandus* is an entirely different species, living in a very different environmental zone, feeding on different fodder growing on a different substrate, and hence subject to quite different environmental pressures, the age groups resulting from this analysis cannot be expected to accurately reproduce those of the original animal population represented. Furthermore, it is well known that the technique does not always provide an accurate indication of the ages of the animals represented, even when adequate comparative material of the proper species is present (Gilbert, 1970; Redmond, 1954; Ryel *et al*., 1961). However, while accurate age correlations cannot be expected, the resulting relative or floating sequence of age classes does provide a pattern which can be compared from one level to another. Species other than ringed seal, bearded seal, and caribou are represented in quantities too small to provide adequate information for this technique.

Data on epiphyseal closure proved valuable primarily for the phocid seals. Only the six major long bones provided sample sizes sufficient to warrant their use, yielding a total of 12 fusion sites for consideration. However, an examination of the raw data seemed to indicate that the presence or absence of epiphyses had not been recorded consistently for all the fibula, due to the fibula's attachment to the tibia in the adult animal. Eliminating the fibula from consideration left ten fusion sites to provide data for this method.

ANALYSIS

Once identification, including aging, is complete, the research problem requires four analysis procedures, two of which are faunal techniques and two of which are statistical techniques. The two faunal techniques include 1) a technique to demonstrate the relative importance in the faunal sample of the species identified from the bones, and 2) a procedure to determine at what season or seasons of the year the site may have been occupied. The statistical techniques include 1) a technique to show that the relative importance of different species does not change significantly from the earliest to the latest part of the site, and 2) a technique to show the degree of variability over time in the presence of particular species.

There are three kinds of measures which can be used for faunal data, 1) Direct Measures, 2) Indirect Measures, and 3) Inferred Measures, and there are two forms of Inference, 1) Pattern Inference, and 2) Reconstructive Inference. Whether the problem demands information based on the species structure or the age structure of the data sample, or of some variable inferred from the data sample, the kind of measure and the form of inference chosen depend on three considerations. The first consideration is appropriateness for solving the problem. The assumptions required by each form of inference are the second consideration. Ideally, the choice should be the form of inference having the fewest and the most innocuous assumptions. Finally, there should be some consideration of practical matters, such as how easy the various measures are to calculate.

Since the distinctions with regard to measures and inference made above represent a new way of looking at faunal data, it is appropriate to discuss them at greater length. The following discussion will attempt to define each kind of measure and relate it to the type of inference for which it is most appropriate. It also will delineate the assumptions which are necessary when each form of inference is employed. Since the measure and form of inference which are chosen and the assumptions which apply to them are also dependent on the other analysis procedures required by the problem, this consideration of assumptions will be closely linked to a discussion of the four faunal techniques available for determining the relative importance of the different species identified in the sample. Finally, the discussion will evaluate the usefulness of each kind of measure and each form of inference in relation to the four techniques for testing the hypotheses generated by this research problem.

Since the following discussion is basic to the way this research has handled faunal data, it may be helpful at the outset to clarify two potentially confusing terms that are used with a meaning which is somewhat narrower than their meaning in ordinary parlance. These terms are "pattern" and "relationship". Within any given faunal sample there is, for example, a relative importance relationship among the various species represented. One way this relationship can be expressed is as counts transformed to percentages and illustrated by a bar graph. Thus Figure 28 shows such a relationship for the sample from square 5L5. For the purposes of this discussion, the term "relationship" applies to the proportions among either data values or inferred variable values from a single sample.

Some of the hypotheses tested in this research, however, require the comparison of the relationships among either data values or inferred variable values from more than one sample. When a minimum of three samples is present, it is possible to establish the existence of what is called, in the context of this discussion, a "pattern". The existence of a pattern among the three levels of square 5L5, based on the relative importance relationship among the various species represented in the data, is shown in Figure 28. A "pattern" is the recurrence in some minimal number of samples (usually three, but a particular problem may require more) of sets of relationships which, for the purposes of the problem, can be shown to be identical.

The three forms of measurement used for faunal remains can be delineated without a great deal of discussion. A Direct Measure, very much as its name indicates, is based on a direct relationship among the material recovered, usually count or weight. Similarly, an Indirect Measure is based on a transformation, much like a statistical transformation, performed on a Direct Measure. The minimum number of individuals is an example of an Indirect Measure. An Inferred Measure is based on either a Direct Measure or an Indirect Measure and requires an inference involving both this measure and some further information about the animals under study, such as estimated dressed meat weight. The weight of meat harvested from each animal of a given species is an example of an Inferred Measure.

The different forms of inference listed earlier require different kinds of measures (see Figure 28), depending on the problem under consideration. Pattern Inference is used when the problem requires a simple description of the data from a sample. Pattern Inference is also used for hypothesis tests which assert the existence, among a set of samples, of one or more patterns, and state predictions concerning how these patterns should vary over space or through time.

It is important to note two characteristics of Pattern Inference. First when used for hypothesis testing, the test implications make assertions about pattern(s) which should exist in the data, not pattern(s) which once existed among the fauna at the time of human occupation. Second, these test implications make assertions about the pattern(s) which should exist among the data, but not the sets of relationships within each sample which go to make up the pattern(s). Because Pattern Inference is used to test hypotheses about pattern(s) which exist in the data, Direct, or occasionally Indirect Measures must be used. Direct (and under some conditions, Indirect) Measure units accurately reflect variability among the samples, but they do not purport to produce an unbiased replication of the faunal relationships which existed at the time the site was occupied. It is important to point out at this juncture that Direct Measures can and do characterize the relationships among the faunal remains represented within a particular sample. However, it is not necessary to specify the nature of those relationships in the test implication in order to use a Direct Measure.

By contrast, Reconstructive Inference is used primarily to replicate or reproduce a set of relationships which are hypothesized to have existed among the fauna at the time of human occupation. These relationships may be used either in a purely descriptive or in a hypothesis testing mode. Reconstructive Inference may also be used for hypothesis

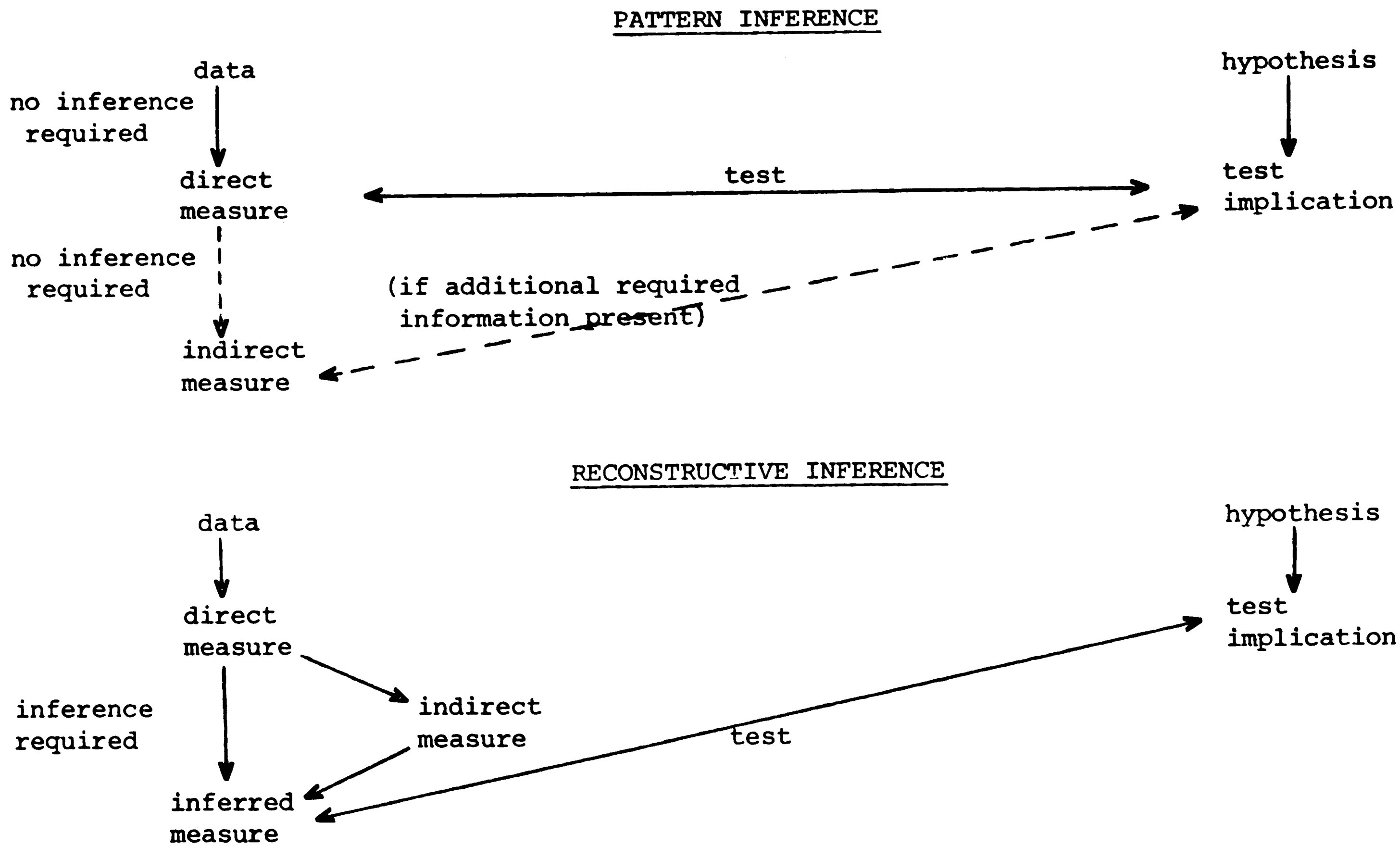

Figure 28. A Comparison of Pattern Inference and Reconstructive Inference.

testing in which the test implications make assertions about the patterms which once existed through space or over time among the fauna when it was utilized. Once again, two characteristics are important. Reconstructive Inference is used to test implications about the relationships, and sometimes also the patterns, which existed among the fauna at the time of human occupation, not implications about the relationships and the patterns which can be found in the data. Second, whether or not the test implications make assertions about patterns, whenever Reconstructive Inference is used for hypothesis testing, the relationships reconstructed from the sample or samples must be stipulated in the test implication. Because Reconstructive Inference deals only with relationships and patterns which existed among the fauna at the time of human occupation, it requires Inferred Measures. Inferred Measures attempt to replicate or reconstruct faunal relationships such as meat weight or dietary ratios as they once existed in the past, but by their very nature they cannot characterize the relationships which exist among the actual faunal remains.

It should be clear from the above that Direct Measures are used both with Pattern Inference and as the basis for constructing Inferred Measures while Inferred Measures are used exclusively with Reconstructive Inference. However, the role of Indirect Measures is less clear. Indirect Measures are probably most commonly used as the basis for Inferred Measures. Whenever either a Direct or Indirect Measure of some sample data value, such as relative proportion of species based on counts (Direct Measure) or the minimum number of individuals (Indirect Measure), is used as the basis of an Inferred Measure, the sample data value is treated as representative of that value for the faunal population present in the site at the time of human occupation. Indirect Measures may also be used as indicators of sample data relationships which cannot be obtained from Direct Measures. However, to use Indirect Measures adequately, the researcher needs more information about the sample than when a Direct Measure is used. In many cases, this additional information is either not available, or if available, indicates that an Indirect Measure is not appropriate.

Since the distinction between the two forms of inference may not be a familiar one, it might be helpful to think of this distinction as loosely analogous to the distinction between nonparametric and parametric statistical procedures. Like nonparametric statistical tests, Pattern Inference is used to demonstrate trends through time or over space by showing similarities and/or differences and is not particularly involved with the actual numerical values of the variables used. Similarly, Pattern Inference requires fewer, less stringent assumptions about the data. Reconstructive Inference, like parametric statistics, is more concerned with the specific value of the variables involved, and requires the researcher to make numerous and more rigorous assumptions. In part to save repetition below in the discussion of the various techniques used to obtain these measures, it will be helpful at this point, to delineate the basic assumptions which each of these forms of inference requires.

Assumptions

In general terms, these assumptions assert that regardless of which form of inference is used, the investigator exercises some degree of control over those factors which are not part of the hypothesis test. In most cases, the factors which are the subject of the test are c-transforms, and thus the investigator is most concerned about controlling the n- and i- transforms which might confuse the results of the test. However, because of the different requirements of the two forms of inference, the basic assumptions must be made in two different forms. Assuming a c-transform is the subject of the test, if Pattern Inference is used, Basic Assumption 1_{pi} reads:

> All n- and i-transforms presumed to be operating on the data must be controlled to the extent that they affect all the data uniformly.[4]

This version of the assumption is less rigorous than the version necessary for a Reconstructive Inference. Basic Assumption 1_{ri} reads:

> All n- and i-transforms presumed to be operating on the data must be known to the extent that the investigator can make corrections or allowances for their effect so that the original configuration of the data can be approximated.

In addition to Basic Assumption 1_{ri}, Reconstructive Inference requires an additional assumption, Basic Assumption 2_{ri}.

> All c-transforms operating on the data, except that transform which is the subject of the pending test, must be similarly controlled.

Two questions will undoubtedly arise concerning these Basic Assumptions. First, why is there a difference in the stringency of the assumption concerning n- and i-transforms? N-and i-transforms relate primarily to the need for control of preservation processes, adequate sampling, and the use of consistent techniques of recovery, identification and analysis. If, as when Pattern Inference is used, the information required is an accurate indication of whether or not a pattern varies through time or across space, the biasing effects of these transforms, as long as they effect all samples equally, are generally unimportant. By contrast, however, if a Reconstructive Inference is required, the specific effects of the n- and i-transforms must be known so that appropriate correction factors can be applied, and the original faunal relationships replicated as closely as possible.

Second, why is no control of c-transforms required for the use of a Pattern Inference? The underlying reasons are discussed in Chapter 3. Faunal remains are assumed to be a direct result of subsistence activities, and hence faunal data can provide information on subsistence changes. When Basic Assumption 1_{di} is met, contrasting patterns in the faunal remains of contemporary sites can indicate the presence of different subsistence patterns.

Likewise, changes over time in the pattern of faunal remains among the levels in one or more similar sites can indicate temporal change in the subsistence activities carried on there. Various cultural practices may contribute to these differences across space or changes through time. Different species may be hunted, yielding faunal samples with very different species present. The same species may be hunted with different techniques, producing samples in which the same species are present, but represented in different proportions. For example, higher calorie needs may lead to more intensive marrow extraction activities at some sites or periods, resulting in differences in the amount of fragmentation among the remains of some species, and so on. But since the overall pattern and the contrasts or continuities which occur in the pattern are the major concern, the potential bias introduced by fragmentation, for example, is unimportant, because if sampling is adequate and the other n- and i-transforms are held constant, all the samples from the same pattern will be equally affected by it.

Thus, if Pattern Inference is chosen, the Basic Assumption 1_{di} is all that is required. However, if Reconstructive Inference is preferred, it is often necessary to consider a number of additional assumptions. These assumptions apply because Reconstructive Inference uses Inferred Measures such as meat weights or dietary ratios. First, when such measures are used, it is usually presumed that all the bones found in the site (with the exception of intrusive species) were used primarily for human food. Second, it is also presumed that no meat was eaten at the site for which bones are not present. Third, if meat weights are calculated on the basis of the relative weights of the bone, it is assumed that the bone/meat ratio is fairly constant from individual to individual. If standard dressed weights are used as advocated by Cleland (1966), Munson et al. (1971), Parmalee (1965), and White (1953b), it must be presumed that the same proportion of the animal was always used.[5]

Techniques For Constructing Relative Importance Measures

Most archaeologists dealing with faunal remains accept the proposition that measures of the relative importance of the different faunal species are valid units for testing hypotheses about changes in subsistence activities. There are four techniques for constructing these measures. The following section discusses these four techniques and their associated assumptions.

Various researchers have advocated one technique over others as "the best" or "most reliable", yet there is no one "best" method. Some techniques are geared more toward the production of Direct Measures while others are designed more for Indirect Measures. The technique or set of techniques which should be employed depends on the hypotheses generated by the researcher's problem and the character of the data. Sometimes it may be valuable to employ more than one technique, since the conflicts and agreements in the results obtained by different approaches may provide important insights into the various factors affecting the data.

While all of these techniques are discussed in the literature, there is no single reference which examines all four, evaluating their relative strengths and weaknesses, and delineating their required assumptions, particularly in terms of a framework based on the distinction between Pattern and Reconstructive Inference. The technique used for this research is not the one used in most current faunal research, and some of the reasons for its choice are different from those usually given. Therefore, in order to illustrate further how each kind of measure is obtained and to help justify the choice made, each technique is presented and assessed.

<u>The Elements Technique</u> (also called "Fragments Method" (Chaplin, 1971))[6]

<u>Procedure</u>. Direct Measure - The bones and fragments are counted and the totals for each species or category compared. Counts are frequently converted to percentages and presented as either serial or level percentages or both (Ziegler, 1973). Both Indirect Measures, minimum number of individuals and relative frequency (Hesse and Perkins, 1974) are calculated from this Direct Measure.

Inferred Measure - The counts obtained by the procedure for obtaining a Direct Measure are presumed to accurately replicate the relative importance of the faunal species at the time of human occupation. The Inferred Measure is only a proportional, not an absolute measure of species importance.

<u>Assumptions</u>. Direct Measure - Basic Assumption 1_{di}

Inferred Measure - Basic Assumptions 1_{ri} and 2_{ri}, also

1) There is no differential treatment of elements or species, so that the relative frequency of bones and fragments identified for each taxon represented in the sample accurately replicates the relative frequency of the differential faunal species used at the site.
2) Each bone or bone fragment counted is independent, that is, each item counted represents a different bone.

<u>Weaknesses</u>. Direct Measure - none

Inferred Measure

1) Since no researcher has come up with a reasonable way to relate numbers of bones to absolute numbers of animals or pounds of meat, Inferred Measures based on the Elements Technique are limited to the proportions of the different species.
2) The two extra assumptions required for Inferred Measures are frequently unrealistic. Differential treatment of elements and species is clearly a common phenomenon. The frequent fragmentation of the long bones of some species for bone marrow extraction is an example. When such fragmentation occurs, the assumption of independence is also unwarranted.[7]
3) Unidentifiable fragments cannot be included and the

animals they represent are simply removed from the sample.

4) Different animals have different numbers of bones (compare, for example, the pectoral limb of a seal with that of a caribou). While a simple correction can be made to deal with this problem, it is seldom, if ever, applied.

Strengths. Both Direct and Inferred Measures

1) It is simple to calculate; only weight is simpler.
2) It can be applied to data about which only limited information is available, as is often the case for data collected in the past. Only counts and a species list are required.
3) The results have a high degree of statistical reliability. The effective sample size is large compared to the results of the Minimum Number of Individuals Technique, for example (Grayson, 1974a, 1975; Ziegler, 1973).

Weight Technique[8]

Procedure. Direct Measure - The bones and fragments are sorted and weighed.

Inferred Measure - The weights obtained by the procedure for obtaining a Direct Measure are presumed to accurately replicate, in proportional terms, the relative importance of the faunal species at the time of human occupation. If a measure of meat weight, rather than species abundance, is desired, usually a conversion

factor based on a general bone/meat ratio is used to calculate meat weights.[9]

Assumptions. Direct Measure - Basic Assumption 1_{di}

Inferred Measure - Basic Assumptions 1_{ri} and 2_{ri}, also

1) There has been no differential treatment of either elements or species which involved removal from the site or alterations in their identifiability.
2) The weight of the bone accurately replicates the original proportions of either numbers of animals, or meat weights, whichever Inferred Measure is used.
3) If meat weights are used, all the assumptions noted on page 228 associated with Inferred Measures of this kind must be invoked.

Weaknesses. Both Direct and Inferred Measures

1) It is not widely accepted by North American researchers.
2) There is a lack of data for comparison from North American sites.

Inferred Measure

1) There is a lack of data supporting the consistency of the relationship between meat weight and bone weight (Uerpmann, 1971).
2) There is a poor understanding of the kinds of changes in specific weight which bones undergo during the time when they are buried in the ground. Corrections for this bias do not yet exist (Uerpmann, 1971).

Strengths. Both Direct and Inferred Measures

1) It is even simpler and easier to calculate than the Elements Technique.
2) Once the bones are sorted by species, the job of weighing can be done by an untrained worker, resulting in a considerable saving of time and energy for the faunal investigator.
3) It is the fastest and most useful method for rough processing to obtain preliminary results, either as the basis for on-the-spot decisions made during the course of an excavation, or as indicators of what further steps should be taken during the preliminary stages of laboratory analysis.
4) The results have a high degree of statistical reliability. The effective sample size is large compared to the results of the Minimum Number of Individuals Technique, for example (Ziegler, 1973).
5) For most measures, the unidentifiable categories can be used. Even if standard dressed weights are used to calculate an Inferred Measure, an average weight for such categories as "small mammal" may be employed to provide more accurate results (Ziegler, 1973).

Inferred Measure

1) The assumption that there is no differential treatment of elements or species is the least stringent of all the techniques. Particularly where bones are fragmented, the Weight Technique can provide a more accurate replication than any of the other techniques.

2) It is not necessary to assume the independence of each bone fragment.

Minimum Number of Individuals Technique (MNI)[10]

Procedure.[11,12] Indirect Measure - Counts of elements by species are required to calculate the minimum number of individuals. Usually the greatest number of any unique skeletal element (e.g., right humerus, left calcaneum, etc.) is used as the minimum number of individuals.

Inferred Measure - The minimum number of individuals calculated for the sample may be inferred to accurately replicate the minimum number of individuals, or perhaps the proportions of individuals, which once existed at the site. The MNI is usually multiplied by standard dressed meat weights to obtain an Inferred Measure based on meat weight.

Assumptions. Indirect Measure - Basic Assumption 1_{di}

Inferred Measure - Basic Assumption 1_{ri} and 2_{ri}, also

1) There has been no differential treatment of either elements or species which involved removal from the site, fragmentation, or alterations in identifiability.

2) If meat weights are used, all the assumptions noted on page 228 associated with Inferred Measures of this kind must be invoked.

Weaknesses. Both Indirect and Inferred Measures

1) MNI is complex and time consuming to calculate. It also requires more information than either the Elements Technique or the Weights Technique.

2) The MNI Technique lacks the statistical reliability of any of the other techniques. This lack of reliability is due to the smaller effective sample size, and hence the greater problem of sampling error.[13]

3) The MNI Technique makes the less frequent species seem relatively more important, and therefore more common, than either the Elements or the Weight Technique.

4) The way in which units are grouped for calculating MNI can affect the results. Grayson (1973, 1974a) has shown that for a given site, if the MNI is calculated for (1) each excavation unit individually, (2) all the units in each level as a group, and (3) the site as a whole, the site totals for each of the three ways of calculating the minimum number of individuals will be different. Method (1), or the maximum distinction sum will yield the largest total. Method (3) or the minimum distinction sum will be the smallest. Grayson advocates method (2) or calculating the minimum number of individuals by combining the data from all the units within a given level, but not combining different levels. In this way, the sample size is as large as possible, without distorting the results by mixing material from temporally distinct units.

5) The MNI Technique cannot make use of any faunal data which is not identified to the species level.

Inferred Measures

1) The results of the MNI Technique are easily distorted if the data is fragmented.

2) The MNI Technique may be less accurate than the Weight Technique for calculating a measure based on meat weight. On occasions when only a part of an animal was brought back to the site and the meat from that part alone consumed, the bones for that hind-quarter, for example, may be counted as representative of a whole individual, and the meat weight calculated accordingly. If the Weight Technique had been used, the meat weight from only the hind-quarter, instead of the whole animal, would be included in the total.

<u>Strengths</u>. Both Indirect and Inferred Measures

1) Intuitive appeal of a measure which is easily visualized in concrete terms (Grayson, 1973).

Indirect Measure

1) It provides an alternative way of looking at the data which can be very useful if the additional information required is present.

Inferred Measure

1) The assumption that there is no differential treatment of elements or species is less stringent than for the Elements Method but not as relaxed as for the Weight Method.

2) It does not require any corrections for differences in skeletal pattern.

Relative Frequency Technique (RF)[14]

Procedure. Indirect Measure - The number of bones present for each element in each species is counted, the counts are corrected for the differences in skeletal pattern and then listed in rank order. After statistical manipulation designed to remove the influence of elements which may be over-represented, the arithmetic mean of this list is used as an indication of the relative number of individuals present, which is then presented as a ratio. Like the MNI Technique, counts of elements by species are required as the basis for calculation.

Inferred Measure - The ratio of species present in the sample may be treated as an accurate replication of the species proportions among the fauna harvested by human occupants of the site. The species ratio may also be multiplied by the standard dressed meat weight for each species to produce a ratio of meat weight rather than number of individuals. In either case the resulting measure is a proportional rather than absolute measure of species importance.

Assumptions. Indirect Measure - Basic Assumption 1_{di}

Inferred Measure - Basic Assumption 1_{ri} and 2_{ri}, also

1) Very few faunal remains have survived the effects of the various processes which have operated on the data. Therefore each fragment found can safely be regarded as coming from a different individual.

2) There has been no differential treatment of either elements or species which involved removal from the site, fragmentation or alterations in identifiability.

3) If meat weights are used, all the assumptions noted on page 228 associated with Inferred Measures of this kind must be invoked.

Weaknesses. Both Indirect and Inferred Measures

1) Faunal specimens which are not identified to the species level cannot be used.

2) The calculation procedure is the most complex and time consuming of all the techniques. Like MNI, it requires more information than the Elements or Weight Technique.

3) It is necessary to correct for differences in skeletal pattern.

4) The way units are grouped for calculating RF can affect the results in much the same way it can affect MNI.

Inferred Measures

1) The assumption that each fragment found can be assumed to come from a different individual is rarely tenable. Clearly many sites provide unmistakable indications that a number of processes ranging from the scavenging of dogs (Casteel, 1971; Guilday, 1971; Higham, 1968; Lyon, 1970; Munson, 1974) to the vagaries of preservation (Guilday, 1970; Olsen, 1971) prevent a large portion of the faunal remains left at any given site

from reaching the investigator. Nevertheless, to assume that only one bone from each animal survives in a fashion that is representative of the original population is generally not possible.

<u>Strengths</u>. Both Indirect and Inferred Measures

1) It has a higher effective sample size than MNI, and thus has greater statistical reliability (Hesse and Perkins, 1974).

Indirect Measure

1) It provides an alternative way of looking at the data which can be very useful, if the additional information required is present.

Inferred Measure

1) The RF Technique is more robust to the violation of the assumption concerning differential use of species or elements than the MNI Technique.

Choice of Inference, Measure, and Relative Importance Technique

Now that the various kinds of measures and forms of inference have been examined and the techniques for determining the relative importance of the different species have been summarized and evaluated, the question of which kind of measure and which technique is most appropriate for this research can be addressed. Returning to Table 4 it is clear that Tests I.A.4, II.A.2.a. & b, II.A.4., and III.A.I. require information showing whether or not a pattern in the data has undergone change over time. None of these Tests specify the set of relationships which is expected to constitute the pattern, but in each case the requirement for a minimum of three data points necessary to establish change over time can be met. Therefore, Pattern Inference based on Direct Measures is the only possible choice for these tests.

Tests I.A.3., II.A.2.a. & b., II.A.4, and III.A.1. require the use of some technique for determining the relative importance of the identified species, or the species structure of the sample. Since a Direct Measure has been selected, either the Elements or the Weight Technique must be used. Ideally, in this situation where the bones from at least one species are quite fragmentary, both techniques should be tried and the results compared. However, data suitable for use with the Weight Technique were not gathered, and therefore the Elements Technique must be used alone.

In contrast to the Tests mentioned above, Tests III.B.2.b. and III. C.2.b. require that a specified set of relationships, in this case the age structure, expected among the phocid seals at a specified season of the year, be matched by a similar set of relationships in the data. Such a Test does not even mention a pattern but is concerned only with a specific set of relationships. Thus Reconstructive Inference based on an Inferred Measure or age is clearly the choice for this test. One set of tests remains, Tests III.B.1.a. and III.C.2.a. However, since these Tests only require showing that species with the appropriate life history occur in the sample, the data for this test can come directly from identification without analysis or formulation as a particular kind of measure.

There are definite advantages to being able to use Pattern Inference based on Direct Measures for so many of the tests. When Direct Measures are employed, there are fewer opportunities for potentially questionable assumptions and/or inferences to come between the data as gathered and the units which are used for the test. Pattern Inference itself requires many fewer and less limiting assumptions than Reconstructive Inference. Instead of the two Basic Assumptions essential for Reconstructive Inference, only one Basic Assumption which is less strict in its requirements is needed for Pattern Inference. Obtaining sufficient information about the sample to control all of the c-, n-, and i-transforms operating on the data except the transform being tested, as Reconstructive Inference requires, is a very difficult condition to meet.

Aside from the Basic Assumptions, the three additional assumptions necessary when the Inferred Measures used for Reconstructive Inference are employed add further difficult hurdles. Ethnographic data from the arctic provide many examples of animals kept or killed for purposes other than human food, and with the fauna serving as the only resource for many kinds of materials, it is reasonable to suggest that this was the case in the past. Thus, to assume that all faunal remains represent food animals may be very misleading.

It is also known from ethnographic information that where large animals and/or long distances are involved, only some parts of the animal may be utilized, all or part of the animal may be cached, or meat may be removed from the carcass for easier transport. In many instances, it may be unrealistic to assume that all the animals killed for the food which was eaten at the site will be represented by faunal remains which were deposited at the site.

As for bone/meat ratios, very little research has been carried out which would demonstrate the consistency of the ratio required by this assumption. White (1953b), at least, believes the ratio is not highly consistent. Alternatively, the use of standard dressed weights also has a high potential for inaccuracy since there is often significant variation in the amount of animals used, not only between groups, but also between different seasons of the year by the same group. Finally whether the bone/meat ratio or a standard dressed weight is used to calculate meat weights, presumptions must be made about the weight of animals, such as early domesticated forms and extinct species, which are no longer in existence.

Additionally, when Reconstructive Inference and hence an Inferred Measure is used to determine relative species importance, extra assumptions are required depending upon which technique is employed. Among the most obvious examples are the assumptions that there is no differential treatment of species and elements and that each fragment represents a different bone when Inferred Measures are constructed using the Elements Technique.

There are two pragmatic advantages to Direct Measures which Inferred Measures do not have. Direct Measures are simpler and easier to calculate. Inferred Measures all require some form of Direct or Indirect Measure as the basis of their calculation. The inferences and assumptions required by these extra steps provide opportunities for error that do not exist with Direct Measures. There is also less opportunity for confusion concerning what the data encompassed by a Direct Measure means. While the units derived using an Inferred Measure may be more easily dealt with on an intuitive level, they are also more easily confused with reality, allowing the researcher to forget the assumptions and conditions required for their proper use.

Tests

Test II.A.2.a.

Two very simply statistical procedures are involved in testing for continuity in age and species structure of the faunal remains. In the first procedure, the raw counts for each faunal category are transformed to percentages and presented in the form of a bar graph. Similarity, denoting continuity, can be judged by inspection. In the second procedure, the faunal categories are listed by rank order based on frequency. Some of the species categories which have no data or very small totals for some levels have been collapsed into larger categories. A Friedman's Two Way ANOVA by Ranks (Siegal, 1966:166-173) can then be performed on the ranked data.

To perform this test, the data is cast in a contingency table, and the frequencies are replaced by ranks. If the null hypothesis (that all the samples came from the same population) holds true, the distribution of ranks in each column is a matter of chance, and the sum of the ranks for each column will be similar. If, however, the rankings across each row are the same or similar, the sum of the ranks for each column is quite different and the results of the test will be significant.

Thus:

$$X_r^2 = \frac{12}{NK\ (k+1)} \sum_{j=1}^{k} (Rj)^2 - 3N(k+1)$$

where N=number of rows
k=number of columns
Rj=sum of ranks in j^{th} column
$\sum_{j=1}^{k}$ directs one to sum the squares of the sums over all k conditions

(Siegal, 1956 :168)

While the exact power of this test is unknown, the results of testing it against the parametric F-test show that it would be difficult, if not impossible, to say which test is the more powerful (Siegal, 1956: 172).

Implementation. Counts by species categories of the bones and bone fragments from all levels of square 5L5 were converted to percentages and ranks, and Friedman's Two Way ANOVA by Ranks was calculated.

Test II.A.2.b.

Up to this point, the discussion of methods has focused at length on Test II.A.2.a. This intensity of focus, however, is justified because the distinctions between different kinds of measures and different forms of inference which have been made in the preceding section are important for many of the other tests involved in this research. Test II.A.2.b. for this same hypothesis deals in a similar fashion with age structure. The methods for determining whether there is continuity in age structure are very similar to those used for determining continuity of species structure. Just as with species structure, Test II.A.2.b. calls for Direct Measures and Pattern Inference. However, no statistical tests are required for Test II.A.2.b. The results can be ascertained by inspection.

Implementation. Although the caribou and phocid seal mandibles seemed ideal for conducting this test, their occurrence in the levels of square 5L5 was too sporadic to provide enough useful data. For example, no ageable phocid mandibles occurred in level 1. Instead of the mandibles, this test is based entirely on the number of unfused epiphyses on five of the major long bones from the "*Phoca* sp." category. This number, transformed to a percentage, can provide a suitable Direct Measure for this test.

The percentages of unfused epiphyses were calculated by taking from a given level, the number of bones and fragments which either did not have an epiphysis, or were an unfused epiphysis, and then matching and eliminating those that could be parts of the same bone and dividing by the total number of bones and fragments for a given element from that level.

Test II.A.4.a.

This test is very similar to II.A.2.a. It requires the same kind of data and is carried out in a similar manner.

Implementation. Counts by species categories of the bones and bone fragments from square 5L5, the rest of the Nanook Site, KdDq-9, taken as a whole, and the Morrison Site KdDq 7-3, were converted to percentages and ranks and compared.

Test II.B.2

The Test Implication for Test II.B.2 asserts that there will be greater variability over time in the abundance of land mammals than in the quantity of seal mammals found in the sample. Because this test requires data showing how a pattern behaves over time, but does not specify the relationships which compose that pattern, Pattern Inference using a Direct Measure of relative species abundance is appropriate for this test.

As for Test II.A.2.a., this measure consisted of counts of elements. Since the sample size for the various levels is very different, and since the proportion of each sample which is composed of land mammals is considerably smaller than the proportion which is composed of sea mammals, variability must be determined in relative terms. It is not readily evident from inspection. To equalize the effect of sample size, a percentage transformation was the first step. To partially mitigate against the problem of linked percentages, the transformation was performed on the basis of the total sample size for each level including the unidentifieds, not just the identifiable portion of the sample. The statistic used for this test is a very simple one, the Coefficient of Variation. It is based on the standard deviation and is calculated from the formula:

$$CV = \frac{S \times 100}{\bar{Y}}$$

(Sokal and Rohlf, 1968:62)

Implementation. To implement this test, the total number of bones from the caribou and the phocid seals for each level were calculated and the percentage transformation performed. The Coefficient of Variation was applied to each group of species, based on the samples from the four levels of square 5L5.

Tests I.A.3., test of units (1), and III.A.1., test of units (1).

The results for Test II.A.2.a. & b. are also used for Test I.A.3., test of units (1), and Test III.A.1., test of units (1). Thus, the methods and their implementation for these two tests of units are the same as for Test II.A.2.a. & b. which have just been presented.

Tests III.B.1.a., and III.C.2.a.

Determining at what season of the year the site may have been occupied is quite a different problem from determining whether or not the age and species structure of the faunal remains show continuity over time. The first set of tests require Pattern Inference and Direct Measures; the second set require Reconstructive Inference and Inferred Measures for one test and simple Identification data for the other.

Test III.B.1.a. and III.C.2.a. involve demonstrating that the faunal data include one or more species which are present in the site area only during the months of the year when there is open water or when the ground is unfrozen. These two periods coincide very closely, and for the purposes of these tests will include the period from early July to mid or late September. All the mammals, and especially the marine mammals, are present in the area throughout all but the mid-winter months. The sole exception is the harp seal (P. groenlandica), a summer resident; even if it was present among the faunal remains, for reasons noted earlier it was not segregated from the other phocid seals. Thus the migratory waterfowl present the best opportunity for finding evidence of a summer occupation. While many of the migratory species have arrived and even hatched their young by the time of break-up, which usually occurs by early July in this area, some species appear primarily in the fall on their migration southward, and therefore are particularly valuable for this test.

Implementation. Implementing this test involves library research into the life histories of the species found at the site to determine if any of them are resident in the area only during the period from early July to mid or late September.

Tests III.B.1.b. and III.C.2.b.

For Tests III.B.1.b. and III.C.2.b. the expected age relationships of the animals harvested during the warm weather season must be specified; then the observed age relationships reconstructed from the data must be matched against them. If the expected and observed are similar, it is reasonable to argue that the site was occupied during the warm weather season. Thus this test requires Inferred Measures and Reconstructive Inference.

Specifying the age structure anticipated for a given species at a particular season of the year depends heavily on finding information on seasonal movements and segregation by sex and age in the biological literature. In addition to information in the biological literature, ethnographic accounts from the area of concern may also provide data as well as insights into how the age structure of the animals harvested was affected by a given set of cultural and technological patterns. Since it is well known that caribou segregate into seasonal herds based on age and sex, this species would seem to be a good one for determining the seasonality of the site. However, as with numerous animals species in many parts of the arctic, very little is known about the specific details of herd segregation and seasonal movement on the south coast of Baffin Island. Further, the caribou mandibles from the site can be aged in only a relative fashion and therefore are of very limited value in this situation where an Inferred Measure, not a Direct Measure, is required. Yet, there is another species for which there is adequate data from the site, namely the ringed seal. The necessary specific biological information exists for this species, as well. Research by McLaren (1958a&b) in southwestern Baffin Island and by Smith (1973) in Home Bay and Cumberland Sound provides the data on the age structure expected at different seasons of the year which is needed. Therefore, only the ringed seal remains were used for these two tests.

In addition to seasonality, an important geographic factor affects both the age pattern derived from the biological literature and the reconstructed age pattern inferred from the data for the ringed seal. Figure 29 reprinted from McLaren's study (1958a) presents the basic pattern of seasonal movement for the ringed seal. In general, the adult ringed seals tend to inhabit the inshore waters, while the immatures live farther offshore. This basic pattern is disrupted most at spring break-up and autumn freeze-up when younger seals are attracted to the ice edge (McLaren, 1958a:72). Nevertheless, as Figure 29 clearly shows, the complexity of the shoreline may affect the basic pattern. Thus, along very simple shorelines, there is less, sharp age segregation.

The basic pattern of age segregation is also affected by another closely related phenomena, the dispersion of animals from more populous (and hence more complex) areas to less populous (and less complex) areas. The Cape Tanfield area is part of a region classified as having a simpler coastline than the area farther west around Markham Bay, for example (although it is not as simple as areas farther east along the south coast). Despite a somewhat simpler coastline, McLaren (1958a:74) notes that both the Lake Harbour and Cape Dorset areas have reasonably good seal hunting because the very complex stretch of coastline between them shelters large breeding populations. Animals from this more complex area are believed to disperse into adjacent areas with simpler coastlines and smaller populations.

Although similar biological data on ringed seal age structure is available from both Smith's study (1973) and McLaren's study (1958a&b), McLaren's data was chosen to serve as the basis for these two tests. This choice was made because, although Smith's research is more recent, McLaren studied the region east of Cape Dorset in southwestern Baffin

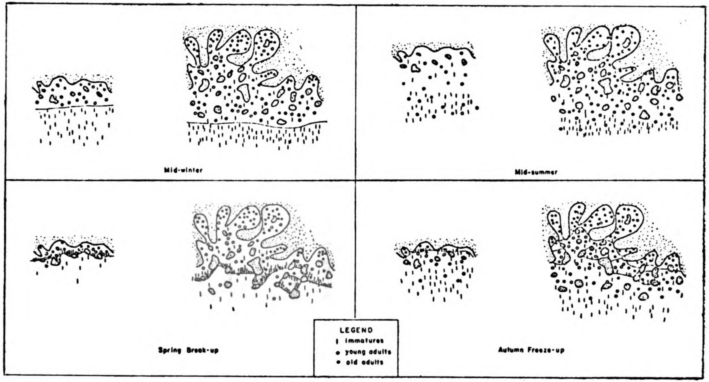

Figure 29. Pattern of annual movement of ringed seal (Phoca hispida). Reprinted from McLaren, 1958a, Figure 28, with permission of the Minister of Supplies and Services, Canada.

Island, an area which is physically closer and geographically more similar to the area around the Nanook Site.

In using McLaren's data (or any data of this type) for comparison with a reconstructed prehistoric faunal sample, several potential biases must be kept in mind. First, a large part of McLaren's sample was garnered by Inuit hunters. McLaren clearly recognizes that this is a bias and that he is not looking at a random sample of the natural population. Nevertheless, for the purposes of this research, this bias is not as great a problem since the sample from the site also represents a hunted population. The difference in technology constitutes a second source of bias. The Inuit who hunted for McLaren's sample used rifles, boats with outboard motors, etc. The occupants of the Nanook Site had harpoons and perhaps boats, but where they hunted (at the breathing hole, at the floe edge?) at different times of the year, what techniques they used, and how this affected their catch is unknown. A third source of bias related to the first two, and like the second, difficult to control, is the inexperience of first year seals. Smith (1973:19) states that young of the year may be overrepresented in some of his samples because it takes time for them to learn to be wary. It is difficult to determine whether this bias also affects prehistoric samples harvested prior to the advent of firearms.

However, to deal more effectively with this problem it is possible to rank the different seasons in terms of their potential for being affected by hunting practices. It is impossible to factor out the effects of the rifle, but differences growing out of some other hunting patterns can be taken into consideration. The summer is least likely to be affected. All animals must be hunted in the open water offshore from boats. Mid to late spring is the next least affected period. Animals are readily accessible at the floe edge or basking on the surface of the ice where they haul out. Freeze-up to early winter ranks third because at this time of the year some animals could have been hunted at breathing holes, and whether or not breathing hole hunting was practiced would have an important effect on the age structure of the catch. Almost all animals taken at the breathing holes would be expected to be sexually mature adults. Finally, mid-winter to early spring would be the most affected, since the most breathing hole hunting, if practiced, would take place during this period.

Since it is hypothesized that the Nanook Site was occupied during the summer, McLaren's data should produce a reasonable basis for comparison, since that is the season when hunting practices would least bias his results. McLaren provides a bar graph (Figure 30) giving the age structure of the sample of animals which were taken offshore near Cape Dorset from mid-July to the end of September. For the purposes of the tests the expected age structure can be derived from this graph and compared with that observed from the ringed seal mandibles in the data. If the expected and the observed age structures match, the tests can be confirmed.[15]

Implementation. If the information given in Figure 30 drawn from McLaren's study (1958a:77) is regrouped so that there are three categories of animals: young of the year, adolescents, and adults, the percentage of animals falling into each category is as follows:

young of the year	adolescents	adults
16.5%	61.2%	22.3%

These percentages constitute the expected age structure for this test.

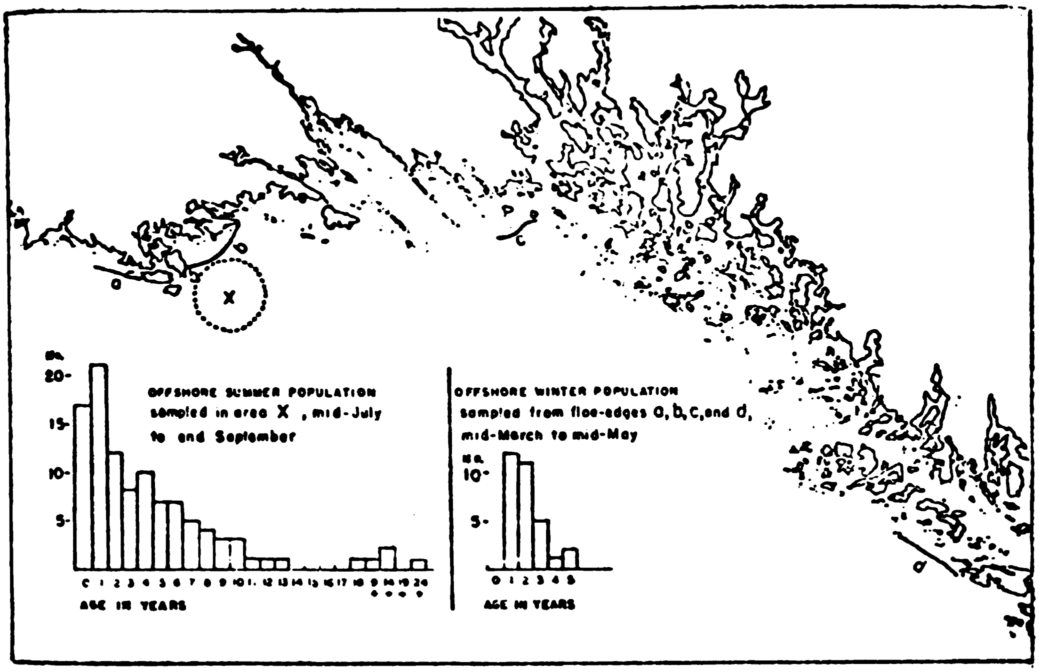

FIGURE 31. Age composition of offshore populations of *Phoca hispida* in southwest Baffin Island in summer and in winter.

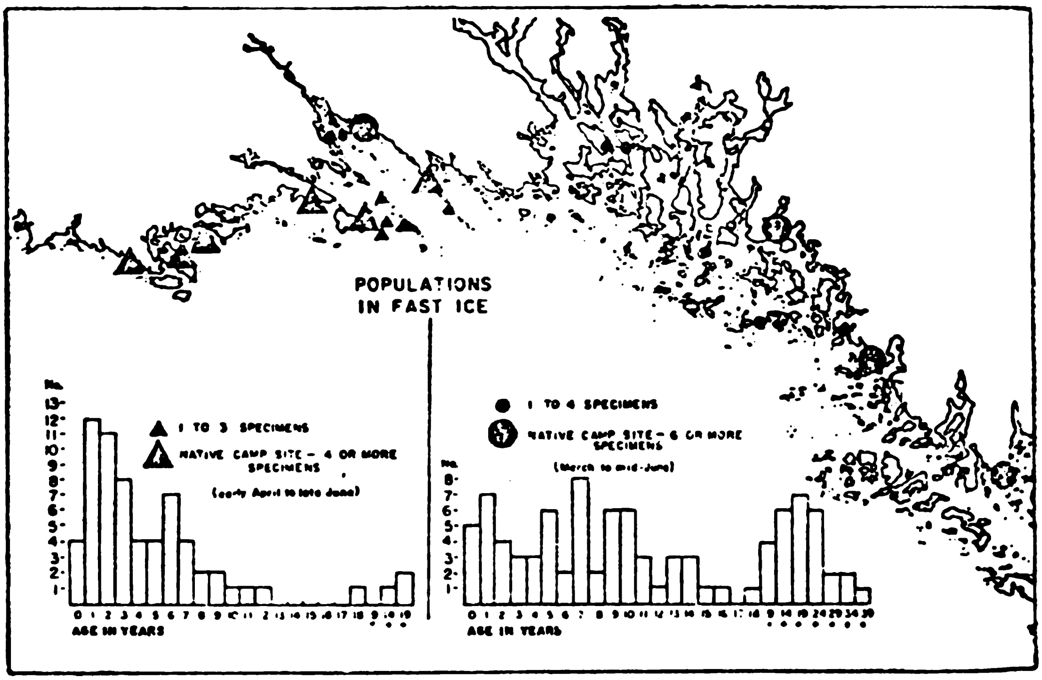

FIGURE 30. Age composition of populations of *Phoca hispida* inhabiting the fast ice of simple and complex coasts of southwest Baffin Island.

Figure 30. Distribution of ringed seals at different seasons of the year. These graphs provide the basis for the expected percentages used in testing for seasonality. Reprinted from McLaren, 1958a, Figures 30,31, with permission of the Minister of Supplies and Services, Canada.

PART 3

ARTIFACT[16] ANALYSIS

INTRODUCTION

To test the hypotheses generated by a research problem, it is necessary to order the information to be studied in a systematic fashion. In dealing with faunal remains, biological classification provides the generally accepted framework for arranging the bones and bone fragments in useful categories. Classification is equally vital for organizing in an intelligible manner the variability found in artifactual data. However, artifact classification does not exist in the same generally accepted form. Therefore, unlike the previous part on faunal remains, this part of Section I will discuss in some detail the particular approach to classification selected and why that choice was made. This part begins with some brief statements on the nature of classification, then proceeds to a discussion of how the classes used were selected, and concludes with a presentation of the methods required by tests using artifactual data and their implementation. Table 6 lists those hypotheses, test implications and tests which require artifactual data. The results of these tests are found in the Results Section of Chapter 5. More detailed descriptions of the artifacts appear in the Site Report Appendix.

BASIC PRINCIPLES: CLASSIFICATION AND VARIABILITY

Any researcher who attempts to use a scientific explanatory approach to problem solving, not only must be concerned with

Table 6. Hypotheses, Test Implications, Tests, and Data required for artifact analysis.

Hypotheses	Test Implications with Tests requiring faunal data	Tests	Artifactual Data required
I. Hypotheses for the Identification of the System Variables			
H.I.A. The Nanook Site is one location used over a period of approximately 500-600 years as the location for the same segment of the unknown local Dorset subsistence-settlement system.	T.I. I.A.4. Artifact units which can be shown to reflect function primarily should show little or no significant change in their types or proportions from earlier to later segments of the site.	T. I.A.4. The percentage frequency of functional class members should be the same or very similar in all the segments of the site.	Percentage frequencies of functional class members for all segments of the site.
		Test of units for T.I.4. (1) Since the artifacts which are members of these functional classes are used to garner and process animal resources, similar patterns of faunal remains should occur in segments of the site with similar patterns of occurrence of functional artifact types.	Percentage frequencies of functional class members for all segments of the site and counts of elements for each species of fauna from each segment of the site.
		Test of units for T.I.4. (2) Since some lithic artifacts with specific functional roles were composite tools with non-lithic counterparts, similar patterns of non-lithic remains should occur in segments of the site with similar patterns of occurrence of functional artifact types.	Percentage frequencies of functional class members for all segments of the site and percentage frequencies of non-lithic items which are known to have a lithic counterpart for all segments of the site.
		Test of units for T.I.4. (3) While artifacts are subject to "misuse" or secondary function, breakage is most likely to occur in the course of normal use, and there is likely to be a correlation between the patterns of occurrence of functional types and breakage patterns in different segments of the site.	Percentage frequencies of functional class members for all segments of the Nanook Site and percentage frequencies of the occurrence of different types of breakage for all segments of the site.
	T.I. I.A.6. Other area sites with contemporary dates and the same locational parameters should show very similar frequencies of functional artifact types.	T. I.A.6. The percentage frequencies of functional class members should be the same or very similar to those of the Nanook Site.	1) Percentage frequencies of functional class members from Levels 1 & 1 of the Kemp Site and from the Morrison Site. 2) Results of T. II.A.1., the cluster analysis.
III. Hypotheses Related to the Operation of the Rule			
H.III.A. If the occupation of the Nanook Site ceased due to a decrease in animal resources brought on by climatic change, other sites in the Cape Tanfield sequence should show a similar sensitivity to climatic change.	T.I. III.A.1. Climatic change brought about the abandonment of the Nanook Site location. One or more essential animal resources decreased as a result of climatic change, and the occupants selected another, more suitable location for their subsistence activities.	T. III.A.1. The entire southern Baffin Island sequence can be shown to be sensitive to climatic change.	Frequencies of functional class members for all southern Baffin Island sites which meet the minimal sample size criterion of N=50.
		Tests of Units for T. III.A.1. Same as test of units for T.I.A.3. above.	Same as for Tests of units noted above.

classification, but also must be conscious of the significant role it plays, and must be explicit about how it is used. Whatever approach to classification is employed, it must be compatible with the Explanatory Model selected for the research. This study utilizes the Pattern Model of explanation because it embodies several distinct advantages: 1) it maintains the distinction between the logical and empirical realms, 2) it stresses the importance of evaluation as providing the opportunity for self-correction, 3) it emphasizes the problem as the basis for evaluation, 4) it requires the investigator to be explicit about the definitions of concepts and units used, and 5) it is highly flexible enabling the investigator to deal with a variety of problems. To be successful, the classification system employed with the Pattern Model must have qualities which parallel and enhance these positive attributes.

The approach to classification used in this research fulfills this requirement. In this approach:

> Systematics functions to convert phenomena into data for a discipline, categorizing historical and time-bound events in such a manner as to create historical units upon which predictions and explanations can be based (Dunnell, 1971a:20).

The easiest way to summarize this approach to classification is to state its six basic principles.

1) Classification is arbitrary; that is, the differentiations made are not inherent in the phenomenological world as the only distinctions possible. Because classification is arbitrary, it is necessary to stipulate certain pieces of information: the field or range of data to be considered; the scale within that field at which classes[17] are to be formed; the attributes of the field, specified at the scale beneath that

at which classes are to be formed; and the specific attributes which are to be selected as criteria for defining classes (Dunnell, 1971a:47-52).

2) Classification is qualitative, not quantitative (Dunnell, 1971a:52-56). This basic principle regards classes as units defined by a set of necessary and sufficient conditions for membership. Classes so defined are monothetic, not polythetic; that is, while each class may have a number of defining criteria, all class members must possess all defining criteria, and no member may lack any of them; within the field selected, a classification should have mutually exclusive and exhaustive units.

3) Classifications are closed formal systems; content is introduced only when members of the classes are identified. Because they are formal structures or organizing devices, classifications are not and cannot be explanatory; they are a means of stating relationships of equivalence and non-equivalence.

4) Naming classes is an arbitrary procedure which has nothing to do with classification itself (Dunnell, 1971a:52-56).

5) Classification has primacy over model-building (Dunnell, 1971a:56-59). Since classificatory units are the building blocks of models and other such structures, the kinds of pieces chosen are going to determine what kinds of models can be built.

6) Classifications must be evaluated. For adequate evaluation to take place, however, the problem and the hypotheses used to solve it must be explicitly stated. Such statements are yardsticks against which the identification of class members involving several choices (e.g., field, scale, specific sttributes) can be measured (Dunnell, 1971a:59-64; Hill

and Evans, 1972). Ultimately, the test of the classification is whether or not it can successfully solve the problem.

Basic to any approach to classification are its assumptions regarding the nature of variability. Archaeological data possess an infinite range of variability, and the meaning of this variability, as well as the correct way to deal with it, have been the subject of considerable controversy. Although the polemic has tended to over-emphasize the polar views (the traditional versus the behaviorist position (Binford, 1972, 1973) or, in similar terms, the empiricist versus the positivist position (Hill and Evans, 1972)) these distinctions have sharpened awareness of the issues involved and thus served a useful purpose.[18]

Since both points of view have been thoroughly characterized in the literature, it is sufficient to point out that the traditional position insists that variability in the archaeological record indicates degree of relatedness or shared cultural background among the people who produced the data. Other factors which cause variability are not given consideration. It is hardly necessary to add that this position is inadequate, and in fact counterproductive for study of an area, such as the arctic, where other sources of variability (for example, the requirements of adapting to a harsh physical environment) make immediate and obvious demands on a population.

The alternative, and more congenial, view is presented in Binford's well-known statement, "Formal variation in artifacts need not, and in most cases, probably does not have a single meaning in the context of the functioning cultural system (1965:206)". This multidimensional perspective recognizes a variety of factors as influencing the human activities which leave archaeological remains. Not only a repertoire of learned cultural background and experience, but also the stimuli produced by changing conditions in both the social and physical environment, influence human behavior. The resulting variability in the archaeological record is created not by one, but by multiple factors (Binford, 1972:132).

However, multidimensional variability in the archaeological record presents the archaeologist with a problem. If the formal variation seen in the data is to be useful for explanation and hence for problem solving, the archaeologist must be able to sort out the different kinds of variability and assign meaning in an accurate fashion. Part of this sorting out process is accomplished through classification.

The traditional point of view toward variability in the archaeological record usually accompanies the traditional model of classification, which Hill and Evans (1972) identify as characteristic of the empiricist approach to archaeology. Briefly, from such an approach, data is collected prior to any consideration of classification, and classification is accomplished by looking for the 'best' classificatory divisions possible. Once types have been established, there is a tendency to see them as <u>the</u> types which are somehow inherent in the data itself (Hill and Evans, 1972).

However, where multiple dimensions are represented by the variability present in the data, the traditional approach to classification is clearly not capable of partitioning that variability and accurately assigning meaning to the resulting units. One alternative to the traditional approach to classification is reflected in the positivist view:

> phenomena do not have inherent or primary meanings to be discovered. Rather, any phenomenon, or set of phenomena, is assigned meaning by the human mind, and it may be assigned as many different meanings as the investigator chooses to give it. The positivist holds that there is no single or best typology of materials and other phenomena. For the archaeologist this means that there is no inherent meaning (e.g., norms, templates, preferences, functions, etc.) to be discovered in an assemblage of artifacts. In fact he can choose to make many different typologies, each with its own meaning. The meanings he chooses to impose depend on *a priori* problems, hypotheses, or other interests (Hill and Evans, 1972:252).

In general, research in arctic archaeology has been characterized by a traditional view of variability and a traditional model of classification. For example, few reports written by arctic researchers recognize the need for more than one all-inclusive classification system. Nevertheless, at the same time, (and here the traditional versus behavioral dichotomy begins to break down) most arctic researchers demonstrate at least some intuitive recognition that some artifact classes and attributes provide more information on one kind of variability than on another. The time has come to take this recognition out of the realm of pure intuition and adopt explicit, scientific approaches to classification, which on the one hand, allow arctic researchers to use these insights, while on the other hand, assure that they will be applied in a replicable and testable manner.

To utilize such an alternative approach to classification, it is helpful to recognize a three-part partitioning of formal variability: functional, stylistic, and technological.[14] The term "functional" has been used in the literature to designate slightly different kinds of formal variation. Therefore, the meaning used here should be explicitly stated. In some archaeological contexts, functional variability is viewed as that which results from "the use of the item in 'tasks' for which it was designed, whether it served in technological, social or ideological contexts (or all of these) (Brown and Freeman, 1964:162)." This definition is very broad, however, and a somewhat narrower definition is more useful for this research. Thus, in this problem, functional variability is viewed as that which results from human adaptation to the natural environment. Using this definition, classificatory units constructed on the basis of functional variation are important for delineating changes in subsistence activities, for example.

In contrast to the use of the term "functional", the term "stylistic" has been used in a somewhat more consistent fashion in the archaeological literature. This consistency in usage probably occurs because the formal variation usually designated as "stylistic" corresponds rather closely to the formal variation frequently used by traditionally-oriented archaeologists to construct their single "best" classification. For the problem in this research, stylistic variability is viewed as that which results from human adaptation to the cultural or social environment. Using this definition, classificatory units constructed on the basis of stylistic variation can be important for delineating various aspects of social organization, such as status, as well as chronology.

The third kind of variability is technological. Technological variability is defined as that which results from the process of artifact manufacture. In many studies, it plays a much less important role than either functional or stylistic variability.

To make the most effective use of data, it is important to examine the particular problem under consideration, decide what kind of variability is most appropriate for testing a specific hypothesis connected with solving that problem, and then isolate the chosen type of formal variability from the data in such a way that the test can be efficiently conducted. If a particular problem generates a number of hypotheses, several different classifications, perhaps constructed at different scales, may be necessary to solve the problem. For other problems, the choice of field may lead the investigator to exclude from classification a large number of items from an assemblage under study. Of course, the same formal attribute may be interpreted in different ways and incorporated into different kinds of classifications for the solution of different problems.

CHOOSING APPROPRIATE CLASSIFICATORY UNITS

The problem which shapes the choice of classificatory units in this study is the question of why the Nanook Site location was abandoned. The hypotheses tested with artifactual data include one hypothesis for the identification of the system variables (H.I.A.) and one hypothesis related to the operation of the rule (H.III.A.). Test Implication I.A. 4. asserts that artifacts which can be shown primarily to reflect adaptation to the natural environment show little or no significant change in their types or proportions within different segments of the site. According to Test Implication I.A.4. other area sites with contemporary dates and the same locational parameters should show very similar frequencies and types of tools. Test Implication III.A.1. asserts that if the occupation of the Nanook Site ceased due to a decrease in animal resources, brought on by climatic change, other sites in the same cultural sequence will show a similar sensitivity to climatic change. Sites dating to the temporal period following the occupation of the Nanook Site which do not appear in the same kind of location as the

Nanook Site, or which have different species and age structure among their faunal remains and different relative frequencies of functional artifact types, will be required to satisfy Test Implication III.A.3. Since both of these hypotheses require data which provides information on subsistence, functional classes are the most appropriate for testing these implications.

Several ways of selecting specific attributes for constructing functional classes have come into existence as the realization has grown that formal variation must be partitioned for effective hypothesis testing. Initially the choice was made on logical or intuitive grounds. Although they are a reasonable place to start, intuitive or logical grounds are not always accurate, and classificatory schemes based on such dimensions usually have not been evaluated. Bordes typology for the Mousterian is an example of a classification devised on such grounds. Variations in the orientation and variations in the form of the working edge were the two major dimensions which served as the basis for the construction of functional classes (Binford, 1973:244-245).

Recently two more elaborate methods have been proposed to perform this task of selecting attributes. Both schemes draw more heavily on theory in their approach to classification, and both emphasize identification of class members from evidence of use on the artifacts themselves. However, the approach used by each method is very different. Cook's (n.d.) scheme selects activity or task as the basic unit of study and uses ethnographic reconstruction of maintenance and extractive tasks to select attributes. In many ways, the units produced by Cook's approach closely parallel those resulting from a technique which produces an

Inferred Measure in Faunal Analysis. Dunnell's (1973) scheme selects evidence of "prehistoric use", primarily wear, and other use-related attributes are selected. Ethnographic reconstruction is explicitly avoided. This procedure yields units which parallel those produced by a Direct Measure technique in Faunal Analysis. Significantly, both Cook and Dunnell emphasize the need to evaluate the resulting classification through testing against independent evidence.

However, for this problem, neither Cook's nor Dunnell's scheme was applied. There is another factor which shapes the selection of attributes and hence the way the classificatory units are constructed. This factor is the source of the data. If some or all of the information required for the study must come from the literature, rather than from first-hand contact with the artifacts, attribute choices are likely to be limited. In such a case, the maximum field is determined, along with the scale at which classes are formed and the scale beneath, used for class defining criteria. The range of specific attributes from which class defining criteria can be chosen is often extremely narrow. All of these limitations restrict what hypotheses can be tested, and such limitations may make impossible the solution of some problems. However, in other situations where an existing classification can be employed, either as is, or with suitable modification, considerable time and energy, (which might have been spent designing and constructing a new classification) can be saved. Regardless of origin, the classificatory system must be tested and evaluated in conjunction with the specific hypothesis and data to be employed in the problem.

Solving the problem in this research is one instance when a modified version of a classificatory system already in use can be employed.

Such a system has been chosen for the reasons noted above: 1) the study requires the use of data which is only available in published form, and 2) a modified version of the existing classification can be used to solve the problem. Of course, a more elaborate functional classification could have been constructed for the Nanook Site data alone. However, in this situation, the time and effort involved could not be justified.

Furthermore, the nature of the tests does not require such a classification, and more importantly, some of the limitations of the data mentioned in the Section of Chapter 4 dealing with the Description of the Site and its Excavation would limit its usefulness. Some of these limitations include:

1) The use of three different systems of reckoning vertical provenience during the course of excavation makes comparison between some segments of the site impossible.

2) While the exact location of many artifacts is plotted, not all artifacts are so precisely located -- further, when these plots were done, a general category of artifact, such as side-notched end blade, or burin, was plotted, not the specific artifact itself.

3) For most squares, there is only one horizontal plot, and plots by level indicating the vertical provenience of many artifacts exist only for parts of the 1970 excavations. Similarly, rock concentrations are not plotted by level so that the vertical locations of rocks is readily reconstructable. Such limitations as these make some kinds of more sophisticated hypothesis testing, (such as that required by Dekin's model for the structure erected on the Closure Site) very difficult, if not impossible.

Nevertheless, even though "literature types" have been used as the basis for the simpler classification system used in this study, it is possible to select a subset of units from that existing classification in such a way that the distinctions represented produce a set of units which have primarily functional meaning. Such a set of units results when distinctions based on attributes potentially representing stylistic or technological variation are eliminated from consideration in this choice.

Regardless of how the class defining attributes are chosen, however, as with any classification procedure, the classification must be evaluated on the basis of the problem at hand, using independent test data. Classes resulting from the implementation of a strategy based on modified "literature types" may not reflect exclusively functional meaning, as in the case of units specifically constructed as functional classes by one of the more elaborate and precise means developed by Cook or Dunnell. However, the use of independent data to test the resulting classification assures a primarily functional meaning, and therefore such classifications can be used for testing hypotheses which require functional data. Further, and very important for this study, the derivation of a classification in this fashion permits the use of data which is available only through the literature.

THE FUNCTIONAL CLASSIFICATION

For this research, two classifications have been used. The first is a set of descriptive classes which have been employed in the Appendix to present the artifactual data from the site which has not been dealt with extensively in the body of the study. The second classification is a set of functional classes which have been employed in tests of

Hypotheses I.A. and III.A.. While the functional classification is not constructed from scratch, it will be valuable in the following discussion to treat if *as if* it were so constructed.

The first step in this construction process is the selection of the field or the range of phenomena to be ordered by the classification. In this instance, the field includes the most common lithic artifacts from the series of Pre-Dorset and Dorset archaeological sites on southern Baffin Island reported by M.S. Maxwell (1973). It also includes, for purposes of testing the classification, many of the lithic items and some of the non-lithic items from the Nanook Site.

Selection of scale constitutes the second step in the construction of functional classes; and stipulation of the scale used for class defining criteria is the third step. In this instance, the scale of classification has been determined by the scale of the existing "literature types". That scale is at the level of discrete object, and the scale beneath it for class defining criteria is that of artifact attribute.

The fourth step, selection of specific attributes has been accomplished by constructing classes based on an existing classification; but, as indicated above, by eliminating or suppressing distinctions which could not be attributed to functional variability. The existing classification, which served as the basis for the units developed for this study, is the one employed by Maxwell (1973) to describe the material from southern Baffin Island presented in his report. To make this set of types suitable for use in this study, class defining criteria were extracted from Maxwell's type descriptions; and, where necessary, information based on personal communication concerning type definition and artifact identification was added. These class definitions are presented in the Appendix and also constitute some of the basic set of classes in the descriptive classification.

Thus, the functional classification was formed by eliminating distinctions based on stylistic or technological variability from the descriptive classification. A total of fifteen functional classes have been constructed for use with the two tests requiring artifactual data. Undoubtedly these fifteen classes do not encompass all of the functional variability displayed by the field which they order. However, if they withstand rigorous evaluation and perform successfully in the hypothesis testing, they will prove sufficient for this research; devising a more elaborate classification system defeats the goal of choosing the approach with the greatest payoff for the effort expended (Chartkoff, 1972).

Although additional functional classes might have been constructed and used, these particular fifteen classes were chosen for use with the two tests requiring artifactual data for several reasons. First, they are all classes whose members are lithic artifacts. Such a choice is appropriate for Test Implication I.A.4. because the recovery of non-lithic items from the Nanook Site has not been conducted on a uniform basis. Therefore, investigator bias may be relatively high for these items. Such a choice is also appropriate for Test Implication III.A.1. because none of the sites dating prior to about 700 B.C. contain non-lithic items; therefore only classes based on lithic artifacts are comparable across sites. The members of the fifteen functional classes comprise a major portion of the artifacts in both the different segments of the Nanook Site and the different assemblages from southern Baffin

Island. Finally, members of all the classes are found in both sets of data.

EVALUATION OF THE FUNCTIONAL CLASSIFICATION

The first priority in evaluating the classification is to consider the problem. From the preceding discussion of the problem and the hypotheses to be tested for its solution, it should be clear that functional units are the most appropriate form of classification. Keeping in mind the problem of explaining why the Nanook Site was abandoned, the arbitrary choices made in the construction of classes and the identification of members must be assessed.

Field. The choice of field is appropriate. No site or site unit in the study area with a sample size greater than 50 has been omitted.[20] With the exception of the Nanook Site material, the data have all been collected and analyzed under the direction of Maxwell, and therefore biases arising from using the work of several different investigators are avoided.

Scale. The issue of scale, however, poses a more serious problem. By choosing to work with a modified existing classificatory system, the scale is fixed at the level of discrete object; yet this scale may not be the most appropriate one for some situations in which functional units are chosen. If an assemblage includes a large proportion of multi-functional, as opposed to unifunctional items, the proper scale may be attribute or attribute cluster, rather than whole artifact.

To deal with this problem, Dunnell (1971b) has developed the concept of "tool" which he defines as the "maximal set of co-occurrent functional attributes associated within the boundaries of a single object (Dunnell, 1971b:21)." If "literature types" at the scale of discrete object are to serve as the basis for a workable functional classification, then: 1) a majority of the "tools" in the assemblage under study must possess functional specificity (that is, they must have been used for limited, specific tasks); and 2) in general, the "tools" should occur one "tool" per discrete object.

It appears that the data used for this study can meet these criteria. Maxwell (1973:344) has argued that Dorset assemblages display a high degree of functional specificity. Further, examination of the artifacts indicates that a minority possesses multiple "tools". A classification strategy based on this approach has already proven successful in Thompson's (1974) study of the development of subsistence patterns in the San Juan Islands of western Washington over the past 3000 years. Further, Binford (1972, 1973) has argued in the presentation of his "functional model" that if a typology, such as Bordes employs for the Mousterian, constructed at the scale of discrete object and based primarily on functional distinctions, is used, functional variability is best measured by artifact type frequencies.

Additionally, artifact type frequencies, rather than the presence or absence of a given artifact type, are a particularly appropriate measure in this instance. As Maxwell's (1973) report demonstrates, change occurs slowly in this area, and artifact types persist over long periods of time. The types which are most likely to show significant variation in their presence are primarily those types which are relatively rare, and hence subject to greater sampling error. Thus, a frequence measure at the scale of discrete object, though dictated by the use of "literature types", is justified as the basis for classification.

Scale of class defining criteria. Using the scale of discrete object for the classification virtually dictates that the scale of attribute will be used for class defining criteria.

Selection of attributes. The remaining choices to be evaluated are the specific attributes selected for class definitions. In using "literature types" however, the attributes selected cannot be evaluated directly. Because "literature types" are frequently used when some or all of the data is not available first hand, the researcher actually selects types rather than attributes. The investigator must then be able to argue that there are significant differences between the types chosen which correspond to distinctions made on the basis of attributes that are functionally significant.

A variety of sources can aid in the identification of those distinctions which may be functionally significant. Logical or intuitive ideas provide some help. Past experience by other researchers using similar data indicates that some units or attributes provide better information on style or function than others. Further, recent research using explicitly functional classifications, which have been formulated and evaluated according to the principles discussed earlier in this section, provide additional suggestions for appropriate dimensions and attributes. Examples of such dimensions are edge angle, edge plan, edge cross-section, edge treatment, placement of edge relative to orientation of the object, and others (see, for example, Dancey, 1974; Dunnell and Fuller, 1975; Dunnell and Lewarch, 1974; Dunnell, Chatters, and Salo, 1974; Rice, 1975; and Watson, n.d.). It can be argued that the groups of artifacts, which result from identifying the members of the classes used in this research, show significant differences in edge angle, edge plan, edge cross-section, edge treatment, edge orientation, and other attributes which other researchers have found to be useful in constructing a useful functional classification. As noted earlier, however, the real test is whether or not the units created (by whatever means) can withstand testing and then successfully solve the problem.

One additional concern arises in connection with evaluating the selection of attributes. In this research, two sets of data have been used: one from the literature and one which was examined first-hand by the author. It is important to make certain that the attributes selected for the class definitions are the same for both sets of data, insuring that the classification of the two sets is comparable. However, since Maxwell's typology serves as the basis for the functional classification, and Maxwell used this typology to classify all the data taken from the literature, comparability can be expected.

Tests of Units. Evaluation of the units which result when the members of these classes are identified can be carried out, at least for the Nanook Site. However, before the methods used for these tests are described, it is valuable to discuss the forms of inference used to carry out these tests, as well as the kinds of bias which can effect the results.

Dekin (1975) has discussed in detail many of the biases which affect artifactual data so that an extensive review here is unnecessary. In the presentation of his ideas, Dekin uses a model of the Constraints on Archaeological Data which closely parallels the concepts of c-, n- and i-transforms used in conjunction with the consideration of Faunal Analysis Methods in the previous section. Some biases affecting artifactual data are summarized in a Table of Ideal Conditions for Recovery of Functional Artifact Data (Table 7), similar to the comparable table for faunal data (Table 5).

Likewise, the forms of inference employed in these tests parallel those for faunal analysis. The same assumptions, delineated in the earlier discussion, apply when these forms of inference are used with artifactual data; and, as in faunal analysis (if the test permits), Pattern Inference is the preferred form because it requires fewer assumptions. Fortunately, the minimum requirement of three samples spanning the period of time under consideration can be met, and Pattern Inference can be used for the Tests and Tests of Units involving artifactual data.

TESTS

Test I.A.3.

For this test, the test implication requires a demonstration that each segment of the site contains tool types with very similar percentage frequencies. Since the results of this test are necessary in order to perform the tests of units, the procedures required will be presented here first, and those required by the Tests of Units will follow.

Perhaps the easiest way to demonstrate similarity in percentage frequencies is through simple histograms; thus, a comparison of histograms is the first step. However, it is also valuable to show this similarity by a statistical test. The problem at first glance appears to be one of goodness-of-fit, and the test which immediately comes to mind is the Chi Square Test run on raw frequencies, since a percentage transformation is inappropriate for data to be used for this test. Initially, problems arise due to cell sizes which are too small to meet the minimum criteria for the test. However, even if Fisher's Exact Test

Table 7. Ideal Conditions for Artifact Analysis.

IDEAL CONDITIONS	PROCESSES WHICH ALTER THESE IDEAL CONDITIONS:
	c-transforms
1. All artifacts of the same type are manufactured in an identical context.	-Quarrying of lithic materials with subsequent transport and trade. - Manufacture of preforms in one location and finished artifacts in another. - Use of different materials from different sources for the same tool type.
2. All debris from the manufacture of a particular artifact type is left in place.	-Use of debris from manufacture of one item as raw material for another. - Use of debris from manufacture for various purposes without modification.
3. All artifacts were used only for their single intended purpose and are then deposited in the context of use with the other tools used in the specific task.	- Curation and storage of tools for future use. - Use of some tools as toys. - Ritual deposition of items, such as in a burial, in context completely foreign to their use. - Emergency or fortuitous use of tools for tasks for which they were not originally manufactured.
5. All artifacts are treated identically in use, leaving characteristic, identical wear patterns. If breakage occurs, it is identical for all artifacts of the same type.	- Individual differences in tool use: how tool is held, amount of pressure applied, and so forth. - Differences in the length of time an artifact is used. - Individual differences in the purposes for which an artifact is used. - Differential reuse of broken artifacts depending on their size, shape, the energy cost of their conversion, and so forth.
6. All artifacts of all materials are equally well-preserved.	- Destruction of artifacts in the course of other activities: by burning, stepping on,

Table 7. (cont.)

IDEAL CONDITIONS	PROCESSES WHICH ALTER THESE IDEAL CONDITIONS:
6. All artifacts of all materials are equally well-preserved. (cont.)	c-transforms dropping, or other destructive acts. n-transforms - All materials preserved equally well. - Differences in the amount or speed of soil deposition in different parts of the site. - Spatial differences in erosion of the site. - Spatial differences, usually vertical, but also horizontal, in the effects of permafrost. - Presence of spatially limited frozen ground phenomena such as frost cracks, etc.
7. All investigators function within the same logistic framework.	i-transforms - Significant differences in money, equipment, time, number of personnel, and other similar factors.
8. All sites are adequately sampled.	- Conditions such as permafrost or heavy vegetational cover prevent access to some parts of site. - Investigators' interests bring about work in only restricted areas of a site. - Investigator lacks knowledge of sampling methods.
9. All artifacts have an equal chance of recovery.	- Differences in recovery techniques, e.g. use of screens, screen size, etc. - Differences in excavator perception and experience. - Differences in investigators' definition of an artifact.
10. All artifacts recovered appear in the data to be analyzed.	- Breakage - Loss in transport or storage - Loss of provenience data

Table 7. (cont.)

IDEAL CONDITIONS	PROCESSES WHICH ALTER THESE IDEAL CONDITIONS:
	i-transforms
11. All investigators collect the same kinds of data.	- Differences in problem. - Differences in the kinds of units and paradigms used by various investigators.

is substituted to solve this problem, other, more serious ones remain. The large number of variables makes any version of the Chi-Square Test awkward to use (Doran and Hodson, 1975:55). Furthermore, when sample sizes are as divergent as those for artifacts from the seven different segments of the Nanook Site, the Chi-Square Test is overly sensitive to small differences, showing units to be significantly different when archaeologically they may not be so.

Another test which has been suggested by Cook (n.d.) is the Kolomogorov-Smirnov (K-S) Test, a non-parametric test of goodness-of-fit which compares cumulative frequency histograms (see also Siegal, 1956: 47-52). Initially this test looks very promising, for it provides an opportunity to distinguish sites on the basis of their cumulative percentage distribution, a device long employed to portray the similarities and differences between sites or units within sites. However, the K-S Test proves to have one serious drawback which Cook did not recognize; it is highly order dependent. To facilitate use of the K-S Test, a computer program was written which converted the raw counts of artifacts to cumulative frequencies, and then performed the test in a pair-wise fashion, as Cook demonstrates. Initially the order of variables used was arranged in a fashion which should have minimized the difference scores which resulted (e.g., those types with large numbers were placed first with those with smaller frequencies following). In subsequent runs, the order of the variables input to the test was randomized, and several runs were made with different variable orderings. The number of pairs for which differences were shown to be significant at the .05 level varied from run to run.

Thus, the K-S Test is subject to the problems of using cumulative frequency curves (or ogives, as Johnson (1968) calls them) brought out quite clearly by Kerrich and Clarke (1967) and the interchange between Irwin and Wormington (1970,1971) and Thomas (1971a). To use the K-S Test legitimately, the problem must include some reason or criterion for ordering the variables in a particular fashion. Since this problem contains no such criterion, the use of the K-S Test cannot be justified.

Cook's use of this test contains a second problem: when a researcher uses multiple pair-wise comparisons in a large data set containing several potential pairs, he or she artificially increases the chance of rejecting the null hypothesis, over a situation in which the multiple comparisons are done in one test. Thus Cook's choice of the Kolomogorov-Smirnoff Test is also inappropriate on other grounds.

However, if the problem is viewed as an analysis of variance problem, it becomes possible to use the non-parametric technique called Friedman's Two-Way Analysis of Variance by Ranks (Siegal, 1956: 166-173), which was used for Test II.A.2.a. in the faunal analysis.

Implementation. CROSSTABS, a computer program from the SPSS series (Nie *et al.*, 1975) was used to tabulate the occurrence of each artifact type by provenience. These frequencies were grouped by site segment, transformed to percentages, and histograms were plotted; then they were converted to ranks for the Friedman's Two-Way Analysis of Variance by Ranks Test.

Test of units 1

Since the artifacts which are members of these functional classes were used to garner and process animal resources, similar patterns of faunal remains should occur in segments of the site with similar patterns of occurrence of functional artifact types. Percentage histograms showing relative species importance, specifically those used to test Hypothesis II.A., were used in the text of this hypothesis as well. Since the artifact percentages for the various segments of the site are very similar, results based on the faunal remains should also be similar.

Implementation. Since the faunal sample was collected in levels from only one square in the site, some grouping of artifacts from different segments is necessary to conduct this test. In the 9-3 component, artifactual data from each level can be compared with faunal data from the level in square 5L5. However, in 9-2, it is necessary to group the artifactual data from the two levels together for comparison, since the faunal sample from the 9-2 component was not collected by level. The faunal data from the 9-1 component is too scanty for meaningful comparison. But, as pointed out with respect to the radiocarbon dates, the 9-1 component is physically contingquous with the 9-3 component and may not represent anything more than a continuation of it. Therefore, not being able to test the units from 9-1 does not pose a serious problem.

Test of units 2

Some lithic items are known to be part of composite tools with non-lithic counterparts. Examples are triangular end blades which fitted the slotted end of a harpoon tip and slate knives which had wooden handles. Thus, those non-lithic remains which were parts of composite tools should show a pattern of occurrence in the different segments of the site similar to that of functional artifact types which are lithic items. Percentage histograms based on the frequency of non-lithic artifact types should suffice for this test. These histograms should show a similar pattern for all segments of the site.

Implementation. Percentage frequencies of all handles, shafts and harpoon tips were used as the basis for this test.

Test of units 3

Although any artifact is subject to "misuse" or secondary use, breakage is most likely to occur in the course of activities for which the artifact was designed. Hence, there is likely to be a correlation between artifact function and breakage. Accordingly, patterns of occurrence of functional types should correlate with breakage patterns in the different segments of the site. Percentage histograms of various breakage categories should show similar patterns in different segments of the site. Friedman's Two-Way Analysis of Variance by Ranks is used to demonstrate this similarity. However, because breakage can be confused with misuse or the results of secondary function, in general patterns of breakage cannot be expected to correlate as closely with functional classes as either faunal remains or non-lithic tools.

Implementation. Seven breakage categories were established, and most of the lithic items in the Nanook collection were tabulated (Table 8). It was necessary to omit some classes from the breakage test, namely cores and core fragments, bifaces, bifacial tool fragments, retouched and utilized flakes. These items were omitted because determining consistently whether these items were "broken" was not possible. It should be noted that the artifact totals for the breakage test are lower than those for the types. The identified items counted in the type totals include, where possible, those items which were recorded in the field catalog but have been lost from the collection. Such items could not be analyzed for breakage characteristics.

Table 8. List of Breakage Categories used for Test of Units (3).

1. Whole
2. Proximal fragments with less than half of artifact present
3. Distal fragment
4. Lateral fragment
5. Medial fragment
6. Broken, but nature of breakage not determinable
7. Distal end broken off but more than half of artifact present

Test I.A.6.

This test, much like Test I.A.3., requires demonstrating that there are similar percentage frequencies among the functional tool types. However, in this case, instead of segments of the same site, the data comes from three different sites.

Implementation. Two other Tanfield Valley sites are probably contemporary with the Nanook Site. Thus, the other sites used for this test are the Morrison Site, KdDq 7-3, and the Kemp Site, KdDq 8-2, Levels 1 & 2 (Maxwell, 1973). Since Test I.A.3. should show that the different segments of the Nanook Site are all very similar, a mean percentage value for the 15 functional types from the seven segments of the Nanook Site is used for this test.

Test III.A.1.

To show that the Nanook Site is part of a cultural system which is responding to the changes in animal resources brought about by climatic change, it is necessary to group the PreDorset and Dorset sites from southern Baffin Island to show that those sites occupied during a fairly homogeneous climatic period are more alike with respect to frequency of functional types than those sites occupied during climatic periods which differed in character. The method chosen to perform this grouping task is a Q-mode Cluster Analysis, based on what is commonly called the average linkage technique.

Cluster analysis begins with a similarity matrix. In the Q-mode approach, archaeological site units are clustered on the basis of several attributes. To form the similarity matrix, which bears a strong resemblance to the mileage chart on a road map, a similarity coefficient of agreement is calculated for all possible pairs of units, and the results placed in a matrix which lists every unit once, both across the top and down the left side in the same order. The diagonal of the matrix is made up of the highest possible coefficient, since it is the agreement of every unit with itself (Cowgill, 1968a:368-369). In this study, the measure employed for calculating the similarity matrix is the Robinson Coefficient of Agreement (Brainerd, 1951; Robinson, 1951). The attributes on which it is calculated are the frequencies of several functional tool types which occur in the appropriate set of PreDorset and Dorset sites from southern Baffin Island.

In the average linkage approach to clustering, the pairs of units having the highest similarity coefficient present in the similarity matrix (other than those on the diagonal) are selected and joined as a cluster. Then the pair of units with the next highest similarity coefficient is selected. They are joined to form another unit unless one of them is already part of the first cluster pair. In that case, the prospective new member of the cluster is checked for its similarity to both members of the original cluster, and added only if the arithmetic mean of its similarity to both units in the original pair is higher than any other remaining coefficient in the matrix. This process continues, forming new clusters in such a way that each link between clusters involves the highest average similarity between members of one cluster and the other.

At the end of the process, all the units in the matrix are linked into one large cluster, and the results are most conveniently displayed by a dendrogram in which each original unit constitutes a separate branch that is eventually joined with others in a cluster at whatever level of similarity is indicated. The dendrogram diagram usually has a similarity scale running along side the figure, so that the level of agreement at which a particular unit joins a cluster can be determined (Cowgill, 1968a:369-370). While this procedure can be performed by hand, computer programs which perform the task, including the dendrogram, are now widely available. (For further discussion of Cluster Analysis and its use in Archaeology, see, for example, Anderberg, 1973; Cowgill, 1968a; Craytor & Johnson, 1968; Doran and Hodson, 1975; Dumond, 1974; Engelbrecht, 1974; Everitt, 1974; Hartigan, 1975; Hodson, 1969a & b, 1970,1971; Hodson, Sneath, and Doran, 1966; Matson and True, 1974; Sokal and Sneath, 1963; Thomas, 1971a; True and Matson, 1970.)

Cluster Analysis is only one of several multivariate methods readily available at many computer installations for the analysis of a data set of this kind. Therefore, it would be valuable at this juncture to discuss why Cluster Analysis was chosen for this test instead of one of these alternative methods. First, the purpose of this test is to group site units to show differences resulting from the responses of their occupants to distinct climatic conditions. Although Cluster Analysis is most frequently discussed in both the biological and archaeological literature as a classification technique used in connection with a numberical taxonomy approach, as Dunnell (1971a) has clearly pointed out, such techniques are more appropriate for grouping units once

classification has taken place. Since this test requires grouping sites on the basis of artifacts which have already been classified, Cluster Analysis is appropriate.

Second, Cluster Analysis requires no prior assumptions about the number of groups or their composition. Such a requirement is in keeping with the Pattern Inference approach used wherever possible in this report. Thus, this method allows the specification of the pattern which should result from the test, namely the correspondence between homogeneous climatic conditions and groups of similar sites, but it does not require the specific reconstruction of these sites. Such latitude is valuable in a situation such as this one because only a few of the site units in the data are well dated. Further, although the site units span a long period of time, various time intervals within that period are not equally well represented. Despite the value of such latitude, it is also important to be aware that this unevenness in the way the temporal periods are sampled will have some influence on the groups which result.

Third, Cluster Analysis is one of the simpler, more straightforward of the multivariate techniques. Since it is reasonable to do Cluster Analysis by hand, it is relatively easy to understand the procedures accomplished by the machine. There is a definite advantage to having a clear understanding of all the various steps undertaken by any statistical procedure used.

Fourth, Cluster Analysis can accommodate data measured at different scales. In this instance the data are frequencies of artifact types, a form of data which, depending in part on the problem, generally gives better results with this method than simple presence/absence data

(Matson and True, 1974). The Robinson Coefficient of Agreement used to order these data in the similarity matrix is a measure which is widely used, well understood, and specifically developed for archaeological data.

Finally, Cluster Analysis appears to have fewer disadvantages than the various alternatives. These alternatives include Factor Analysis, Multidimensional Scaling, and Multiple Discriminant Analysis. The oldest and best known of these alternatives is Factor Analysis. Factor Analysis has been most successfully used in Archaeology by Binford and Binford (1966), Binford (1972), and Hill (1970). The factor scores resulting from Factor Analysis could be used to produce the kind of groups required by this test. However, Factor Analysis was rejected in this instance because it is a more complicated procedure than is required, and because it is not entirely clear that the data can meet its assumptions of linear correlation adequately. Although this concern does not apply to this test, Factor Analysis has the additional disadvantageous requirement of interval scale data.

A second procedure which has been used by archaeologists to group data, as this test requires, is Multidimensional Scaling (Doran and Hodson, 1966; Doran and Hodson, 1975; Hodson, 1969a; Kruskal, 1964a & b; Matson and True, 1974; Shepard, 1962; Shepard, Romney and Nerlove, 1971; True and Matson, 1970). Multidimensional Scaling (or proximity analysis, as it is sometimes called), like Cluster Analysis, works on a similarity matrix and therefore can accomodate data at a variety of scales. Further, as a "nonparametric" technique, Multidimensional Scaling avoids some of the assumptions of Factor Analysis concerning the linear relationship of both the initial data correlations and the resulting factors. Its use also circumvents the complications which arise when a technique based on a correlation matrix is used with data requiring a proportional transformation (Chayes, 1948,1960,1971; Cowgill, 1968a; Dumond, 1974).

However, Multidimensional Scaling has its own drawbacks. The most significant is its sensitivity to the input order of the data. An iterative procedure is used to obtain the best solution, and under some circumstances, iteration may stop before a final solution is obtained; thus yielding different solutions in different "runs" with the same data. (This problem is discussed at greater length in the Results Section dealing with this test.) Not being able to obtain a consistent result from the same set of data is a quality which makes Multidimensional Scaling a less desirable method.

A third possibility is offered by Multiple Discriminant Analysis (Bryan and Teideman, 1954; Cooley and Lohnes, 1962,1971; Saupe, 1965; Smith, 1967; Tatsouka and Teideman, 1954). Multiple Discriminant Analysis shares with Factor Analysis the drawbacks of a fairly complex procedure, the necessity for at least interval scale data, and some essentially parametric assumptions (although it does appear to be very robust to their violation (Doran and Hodson, 1975:211)). Its biggest handicap, however, is that it requires that the data be grouped in some tentative way prior to calculating the statistics. These requirements make it clearly less useful than the others for this test.

The disadvantages of the alternatives which make Cluster Analysis the best choice for this test have been discussed. At the same time Cluster Analysis has its own limitations which should not be overlooked. As Cluster Analysis is used in this study, it employs the Robinson

Coefficient of Agreement which has some important advantages mentioned earlier. However it also has some qualities which can have disadvantageous effects on the data. Perhaps the most important of these is its tendency to give greater weight to more frequent types. Thus, if the differences which are to be demonstrated in the test are based on variability in rare types, constructing the similarity matrix using this technique means that these differences are less likely to be expressed in the results.

Second, there are several approaches to forming clusters among the family of techniques denoted by the term Cluster Analysis. The average linkage approach is clearly superior to the single linkage alternative, and for this problem provides more useful results than double or complete linkage. However, it does have some drawbacks from a mathematical point of view (Jardine, Jardine and Sibson, 1967; Jardine and Sibson, 1968), and it possesses the undesirable quality of permitting units to become "trapped" in a cluster early in the analysis, not allowing them to "escape" later on to a more desirable position in the final result (Hodson, 1970).

Matson and True (1974) in their exploration of various clustering techniques found that the average linkage method, the farthest neighbor method (Johnson, 1967) and the Lance-William's (Lance and William, 1967) Flexible Method gave relatively satisfactory results, although their method of choice was Ward's Error Sum of Squares Cluster Analysis. Unfortunately, none of these alternatives were readily available for use. Nevertheless, the average linkage method has a reasonably good record among archaeologists, in terms of its ability to produce satisfactory results. As Doran and Hodson (1975:177) point out, it may be unrealistic to expect a technique of this kind to be completely respectable from a mathematical point of view and still produce good, useful results. However, because some questions do exist about average linkage Cluster Analysis, (Doran and Hodson, 1975:177; Hodson, 1970) an effort to cross-check the clusters obtained will be made in the Results Section (Section II), using alternative multivariate techniques.

Implementation. The Cluster Analysis for Test III.A.1. was implemented using a total of 32 site units from the southern Baffin Island PreDorset and Dorset sequence reported by Maxwell (1973). Twenty-five of these units come from Maxwell's report on the PreDorset and Dorset sequence from southern Baffin Island; an additional seven units are from the Nanook Site reported in this study. A total of fifteen functional types, tested with the Nanook Site data in Tests of Units for Tests I.A.4. and III.A.1. to show their essentially functional character, were used as the variables for this test. The raw data is listed in Table 9.

The entire Cluster Analysis was performed on the computer facilities at the University of Washington. The similarity matrix was calculated using RBCAL, a program for constructing a similarity matrix based on the Robinson Coefficient of Agreement written by Jerry Jermann. The average linkage Cluster Analysis, using the unweighted pair-group method was then performed using a program based on the work of Bonham-Carter (1967), and the resulting dendrogram was plotted with the Calcomp Plotter. Both of these operations were accomplished using programs which were also adapted or written by Jermann.

Although this issue was mentioned above, it is important to note that there are some significant limitations on the data used for this

Table 9. Raw data used for Cluster Analysis.

SITES	ARTIFACT TYPES	Microblades	End Scrapers	Retouched and Utilized Flakes	Burins	Triangular End Blades	Side Notched End Blades	Side Scrapers	Cores	Burin-likes	Slate End Blades	Bifacial Tool Fragments	End Blade Tips and Fragments	Burin Spalls	Lamp Fragments	
Nanook	.91 11	41	38	2	9	23	7	11	3	12	17	12	7	1	0	1
	.91 12	63	46	15	15	34	21	22	4	13	19	20	6	5	0	0
	.92 11	231	46	43	21	75	50	41	18	41	72	36	8	12	5	7
	92 12	61	27	4	7	18	11	6	2	14	30	10	8	2	2	7
	93 11	135	34	19	12	30	14	12	5	13	24	26	9	8	0	2
	93 12	165	65	40	16	53	23	12	11	27	43	28	10	2	0	4
	93 13	132	46	34	6	34	15	16	7	16	37	29	12	2	0	12
Kemp	8-2 11	70	16	1	1	7	13	3	2	6	22	4	6	4	0	11
	8-2 12	74	21	2	2	13	11	7	4	9	20	6	9	3	0	2
	8-2 13	60	20	3	1	13	11	6	3	10	44	4	11	5	0	3
	8-2 14	65	21	12	12	12	4	6	7	9	41	4	4	6	5	17
Morrison	KDD073	53	17	6	6	12	6	3	7	7	31	1	4	0	1	10
Tanfield	KDD071	1040	127	117	24	215	56	51	211	97	366	169	114	52	3	86
7-1A	KDD074	104	24	4	4	24	6	12	5	8	19	4	16	9	0	8
Kakela	8-3 11	44	6	3	2	3	6	4	5	3	8	3	2	4	0	6
	8-3 12	46	7	1	0	10	1	5	8	3	6	1	4	3	0	4
	8-3 13	35	17	2	3	12	2	5	4	4	18	1	17	0	0	0
	8-3 14	75	11	2	4	14	9	4	3	5	23	9	14	6	0	3
Avinga	KDD081	142	45	11	35	30	16	15	7	14	43	6	14	12	40	16
Sandy	62 11	17	6	3	5	4	5	0	4	0	0	2	5	3	1	0
Davidee	KDD015	43	1	11	4	5	4	2	1	4	4	3	5	3	14	0
	1 12	23	1	12	6	1	1	0	2	1	5	2	1	0	7	0
	1 11	50	3	10	2	9	2	0	4	0	2	2	0	0	4	1
Site 13	KDD013	14	1	4	4	2	2	2	6	0	6	0	0	0	6	0
Killilugak	KED003	347	7	16	22	6	15	1	11	5	7	19	0	9	31	0
Killuktee	KDD019	52	51	13	6	39	60	9	11	6	1	39	12	7	0	5
Talagwak	KED0 2	24	20	5	1	21	21	0	2	3	1	18	7	0	0	1
Lemming	KED0 6	11	7	4	4	7	5	1	2	2	0	13	0	1	0	0
Loon	KDD010	133	43	50	59	13	9	21	12	5	15	19	9	7	54	0
Closure	KDD011	21	4	3	31	2	2	3	2	1	2	4	3	0	20	0
Annawak	KED0 1	21	3	35	35	0	0	7	5	1	1	0	3	0	49	0
Shaymark	KKDN 2	112	3	42	111	15	3	4	10	0	0	6	14	2	185	0

test. These characteristics are viewed as limitations in part because this data was not gathered specifically for this problem, and in part because major changes have occurred in recent years in archaeological data standards. Negligence or lack of what might be considered proper field technique on the part of the excavators are not involved. The first limitation of the data is that the site units employed do not sample the time interval under study in an even fashion. There are a few site units from the early PreDorset period and a few from the late Dorset period, but the majority of the site units sample the early to middle part of the Dorset period. The second limitation is that the samples from these site units differ significantly in size. The largest sample from the Tanfield Site totals 2565 artifacts, whereas the smallest from Site 13 totals only 53 artifacts. Although a proportional transformation in the RBCAL program should preclude the larger samples from influencing the results disproportionately, smaller samples are more subject to sampling error. Rarer types are more likely to be missing, and there is greater chance of variation among those types present.

Dating uncertainties constitute the third uncertainty. As should be evident from Table 10, not all of the sites have radiocarbon dates, and even among those which are dated, many have only one or two dates. As the earlier discussion showed, the uncertainties of radiocarbon dating, particularly on the kinds of materials found in the arctic, add to the problems of temporal control. As the dates from the Nanook Site indicate, some of the sites may have been occupied over a time period spanning several hundred years. There is also the possibility that a few of the sites, such as the Kakela Site, KdDq 8-3, may contain

Table 10. Suggested temporal order of sites used in the Cluster Analysis. Based in part on data from Maxwell, 1973.

Assemblage	Uncorrected C-14 date	Sample material	Sea level elevation in ft.
Closure (KdDq-11)	4460±100 B.P. (GAK-1281) 2510 B.C.	charred fat (seal?)	40
	4690±380 B.P. (GSC-1382) 2740 B.C.	charred fat (seal?)	
	4080±66 B.P. (P-707) 2130 B.C.	charred fat (seal?)	
Annavak (KeDr-1)	3227±62 (P-708) 1877 B.C.	charred fat (seal?)	60
Shaymark (KkDn-2)			50
Loon (KdDq-10)	3590±63 B.P. (P-710) 1640 B.C.	charred fat (seal?)	48
Site 13 (KdDq-13)	3480±200 B.P. (M-1531) 1530 B.C.	charred fat (seal?)	36
Killilugak (KeDr-3)	3056±63 B.P. (P-699) 1106 B.C.	charred fat (seal?)	33
Avinga (KdDq 8-1)			30
Davidee (KdDq-1) surface, level 1, & level 2			29
Tanfield (KdDq7-1)	2626±53 B.P. (P-698) 676 B.C.	charred fat (seal?)	22
	2621±40 B.P. (P-698A) 2671 B.C.	charred fat (seal?)	
	2390±130 B.P. (M-1528) 440 B.C.		
	2250±130 B.P. (M-1528A) 300 B.C.		
Kemp (KdDq 8-2) level 3 & level 4			26
Site 7-1A (KdDq7-1A)	2350±140 B.P. (GSC-820) 400 B.C.	charred fat (seal?)	20
Nanook (KdDq-9) 9-1 Level 2	2410±120 B.P. (M-1535) 460 B.C.	animal fat, seal skin	39
9-2 Level 2	2370±100 B.P. (GAK-1286) 430 B.C.	willow twigs	
9-3 Level 3	2380±80 B.P. (GAK-1284) 420 B.C.	seal skin, caribou skin, & other organic matter	
Kemp (KdDq 8-2) level 1 & level 2	2200±120 B.P. (M-1534) 250 B.C.	charred fat (seal?)	26
Morrison (KdDq7-3)			20
Nanook (KdDq 9) 9-3 Level 2	2220±100 B.P. (GAK-1279) 270 B.C.	sod	40
9-1 Level 1			
9-2 Level 1	1916±61 B.P. (P-704) 34 A.D.	dried sod & grasses	40
	1827±61 B.P. (P-706) 123 A.D.	willow twigs	
9-3 Level 1			
Kakela (KdDq 8-3)			25
Lemming (KeDr-6)			13
Killuktee (KdDq19-20)	1670±150 B.P. (M-1533) 280 A.D.	charred fat (seal?)	12
Sandy (KdDq-2) Level 1)	1470±110 B.P. (M-1529) 480 A.D.	charcoal	15
Talagwak (KeDr-2)			14

artifacts from earlier occupations due to the presence of older artifacts in sod used as a building material. Maxwell has provided reasonable dating estimates for the undated sites, but taken together, the dating uncertainties make control of the outcome of the Cluster Analysis less tight than would be desirable.

Finally, there may be some significant sampling differences between sites, or even between units within the same site due to excavation techniques. While this effect should be minimal because the same individual directed the excavation of all of these units, Dekin (1975:177) notes that Maxwell found that the amount of time expended in excavation had a notable effect on recovery. The problem of improved recognition over time may also enter in. Thus, the samples from those units which were excavated during the early, more rapid and more exploratory phases of research may be biased in comparison with later, more slowly excavated units.

However, if the investigator waited until the perfect set of data is available to conduct tests and do research, the work would never be done. A large amount of valuable time and effort has been expended in collecting this material, and it should not go to waste because of these rather common shortcomings. If the potential problems are kept in mind and their potential effects recognized, and wherever possible controlled, useful analysis can take place.

Test III.A.3.

Test III.A.3. requires demonstrating that those sites which follow the Nanook Site in time have different locational parameters, or different patterns of faunal remains and different relative frequencies of functional artifact types. The method employed in Test III.A.1., Cluster Analysis, should yield data which will permit at least partial teating of this implication.

Implementation. Three sites later than the Nanook Site in date appear in the southern Baffin Island sequence: the Killuktee Site, KdDq 19, the Talagwak Site, KeDq 2, and the Lemming Site, KdDr 6. (Maxwell, 1973). None of these sites have faunal remains. However, they all have sufficiently large samples that they can be used for Cluster Analysis.