PHOTOGRAPH THIS SHEET

AD-A955 001

DTIC ACCESSION NUMBER

LEVEL

INVENTORY

1

ADTIC PUB. A-107

MAN IN THE ARCTIC

DOCUMENT IDENTIFICATION

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR	
NTIS GRA&I	✓
DTIC TAB	
UNANNOUNCED	✓
JUSTIFICATION	
BY	
DISTRIBUTION /	
AVAILABILITY CODES	
DIST	AVAIL AND/OR SPECIAL
A-1	

DISTRIBUTION STAMP

QUALITY INSPECTED 3

UNANNOUNCED

DTIC
ELECTE
JAN 0 6 1986
S D
D

DATE ACCESSIONED

DATE RETURNED

86 1 3 082

DATE RECEIVED IN DTIC

REGISTERED OR CERTIFIED NO.

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDAC

DTIC FORM 70A DEC 83

DOCUMENT PROCESSING SHEET

PREVIOUS EDITION MAY BE USED UNTIL STOCK IS EXHAUSTED.

ADTIC PUBLICATION A-107

MAN IN THE ARCTIC

The Changing Nature of His Quest for Food and Water as Related to Snow, Ice, and Permafrost

By
Harley J. Walker

January 1962

Arctic, Desert, Tropic Information Center
Research Studies Institute
Maxwell Air Force Base, Alabama

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR UNIVERSITY
MAXWELL AIR FORCE BASE AL 36112-5001

17 June 85

REPLY TO ATTN OF: PA

SUBJECT: Security & Polciy Review

TO: AU/LDEX

The attached ADTIC publication, NO. A-107, titled: "Man in the Arctic," is approved for release IAW AFR190-1.

ALAN J. ROD, GS-12
Deputy Director
Public Affairs

1 Atch
Report

ADTIC PUBLICATION A-107

MAN IN THE ARCTIC

The Changing Nature of His Quest for Food and Water as Related to Snow, Ice, and Permafrost

Prepared Under an Air University Grant

By

Harley J. Walker

Louisiana State University

January 1962

Arctic, Desert, Tropic Information Center
Research Studies Institute
Maxwell Air Force Base, Alabama

Contents

List of Figures

INTRODUCTION

IN RECENT years scientists, engineers, business men, and military specialists have displayed an ever increasing interest in the Arctic, an interest that has been translated into the study and development of the American Arctic on a scale never before attempted. Such developments as the Distant Early Warning Line, Thule Air Base, Arctic Research Laboratory, relocation of Aklavik, daily weather flights over the North Pole, submarine navigation under the polar ice pack, and establishment of scientific stations on ice islands all give testimony to today's attitudes toward the significance of the arctic. Such developments have led to a demand for information about the arctic environment in general and how it relates to living and working in the Arctic in particular.

Among the many environmental factors affecting arctic activities are those of snow, ice, and permafrost. These factors cannot be ignored by man whether he be Eskimo or white, or whether he be hunter, explorer, or scientist. All of these groups, and more, in the course of arctic history, have developed techniques for utilizing and combating snow, ice, and permafrost—techniques which have varied greatly in complexity and efficiency.

Snow, ice, and permafrost, with their manifold properties and variable temporal and regional distribution, have a direct bearing on man's quest for water and food in the Arctic. Some of the techniques he has developed utilize snow, ice, and permafrost directly, as when snow and ice are converted to drinking water, and indirectly, as when sea ice serves as a platform for hunting seals. Snow, ice, and permafrost may be beneficial or they may be a hindrance in man's quest for water and food. Just which role they assume is often dependent upon the culture of the group directly concerned at any one time. The Eskimos, who were dependent entirely upon the region considered, utilized and reacted to snow, ice, and permafrost in quite a different way than did the explorers and they, in turn, from today's inhabitants. The Eskimos in developing their technology have taken advantage of special properties of snow, ice, and permafrost to an amazingly high degree. Some of their methods of obtaining food and water have been adopted by immigrants, some have been altered, others added.

Today in the Arctic man is dependent on the region for his water supply just as were the pre-contact Eskimos but, unlike the Eskimos (or, for that matter, the explorers), today's inhabitants demand a greater quantity and better quality of water. Low-demand techniques have proven unsatisfactory and new methods have evolved—new methods which are closely related to snow, ice, and permafrost. In the case of food, today's non-native derives little locally. Recent rapid developments in transportation have made possible dependable supplies from temperate regions, albeit at high cost. As a result, snow, ice, and permafrost are much less significant in this phase of man's subsistence than they once were.

The objective of this study* is to detail the techniques used in the American Arctic by man in his quest for food and water insofar as they are related to snow, ice, and permafrost, and to evaluate these techniques and the changes that have occurred in them in terms of today's needs.

* Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

The research and preparation of this study was made possible by the United States Air Force through an Air University Research Grant which provided financial support and the use of the facilities of the Air University, Maxwell Air Force Base, Alabama. This grant also made possible contacts with numerous individuals knowledgeable about the Arctic. To Dr. Paul H. Nesbitt, Chief of the Arctic, Desert, Tropic Information Center, Research Studies Institute, and to the members of his staff, I express my appreciation for the many hours of assistance they accorded me.

In addition, acknowledgment is made to the following individuals and institutions for the important contributions they have made: Dr. Vilhjalmur Stefansson; the Stefansson Library; the Western Electric Corporation; the staff at each of the DEW Line stations visited; Father Van de Velde, Pelly Bay, Canada; and Iwo, who introduce me to some of the techniques needed in winter living in the Arctic.

Lastly, I wish to express my thanks to Professor Fred B. Kniffen for the knowledge and good counsel he offered throughout the entire study.

NOTE TO THE READER

The *Arctic Bibliography*,[1] which contains over 49,000 abstracted entries in the eight volumes published to date, has become the standard source of reference to arctic publications since the first three volumes appeared in 1953. Because of its significance and because approximately 70 per cent of all reference items used in the present study are abstracted in it, the style of footnote in the present study has been altered somewhat to partially conform with that used in the *Arctic Bibliography*.

All maps showing sea-ice distribution have been adapted from the *Ice atlas of the Northern Hemisphere*[2] and from "Comparative ice conditions in North American Arctic, 1953 to 1955, inclusive."[3] The maps of snow distribution are based on the atlas entitled *Depth of snow cover in the Northern Hemisphere*[4] and the maps contained in the article "Snow cover in Canada."[5] Sources used in the construction of maps other than the four indicated above are cited on the maps concerned.

All photographs unless otherwise acknowledged were taken by the author.

The spellings and definitions of the common as well as the technical terms used in this study follow the *Glossary of arctic and subarctic terms*.[6]

[1] Prepared for and in cooperation with the Department of Defense under the direction of The Arctic Institute of North America, 8 vols. U. S. Government Printing Office, Washington (1953-1959).
[2] U. S. Navy, Hydrographic Office, Pub. no. 550 (1946).
[3] Schule and Wittmann, Transactions, American Geophysical Union, XXXIX, no. 3 (1958).
[4] U. S. Army, Corps of Engineers, Arctic Construction and Frost Effects Laboratory (Boston: U. S. Corps of Engineers, 1954).
[5] Boughner and Potter, *Weatherwise*, VI, no. 6 (1953).
[6] U. S. Air Force, Arctic, Desert, Tropic Information Center, Pub. A-105 (1955).

The Physical and Cultural Base

The Areal Limits

The term "Arctic," used in general to refer to that part of the earth surrounding and including the Arctic Ocean, has come to have a variety of specific definitions since it was first coined. The original astronomical meaning of the term for the region north of the Arctic Circle was found to be of limited value, for this parallel does not coincide with any of the natural boundary lines occurring within the distributions of such variables as climate, vegetation, permafrost, and sea ice. As a result, through the years the Arctic has been evaluated many times from the standpoint of various physical, biotic, and cultural variables. The result has been the creation of several "Arctics," each varying from the others in geographic limits.

For the purposes of this paper, no one definition is completely satisfactory. The tree line (Figure 1) probably furnishes the best of the natural boundaries for several reasons. In general, there are rather definite differences between the forest area to the south and the tundra to the north in snow-cover characteristics, wind conditions, and animal types as well as vegetation. The equipment and clothing used in these two contrasting environments frequently differ, as do methods of snow utilization. The tree line also corresponds rather closely with the inland limit of Eskimo distribution.

As used in this study, the term "Arctic" refers to the area poleward of the tree line in North America, including Greenland, with the following exceptions: the Aleutian Islands are excluded whereas the relatively small areas of forest utilized by the Eskimos either occasionally or habitually along the Labrador Coast, parts of Alaska's west coast, Mackenzie Delta, and Brooks Range are included.[1] The term "North" is used when a more inclusive term is needed and refers to the area generally considered as Subarctic and Arctic combined.

The Physical Base

Structure and Landforms

The American Arctic, structurally a northward extension of lower latitudes, is composed of three physiographic divisions (Figure 1). The Canadian Shield Division, largely pre-Cambrian in age, includes some four-fifths of the American Arctic. Greenland is usually included; however, J. Tuzo Wilson thinks that Greenland should be considered a separate continental structure because of the width and depth of Baffin Bay.[2] The Cana-

[1] The most commonly used boundary line for the Arctic is one based on temperature conditions. Climatically the Arctic is generally considered as containing no month with an average temperature of over 50° F. and at least one month with an average below 32° F. These criteria were chosen because they form an isopleth which closely approximates the tree line.

[2] "Geology of Northern Canada," *Canadian North*, compiled by J. J. Arens (Washington: U. S. Office of Naval Operations, 1956), chap. xiv, p. 405.

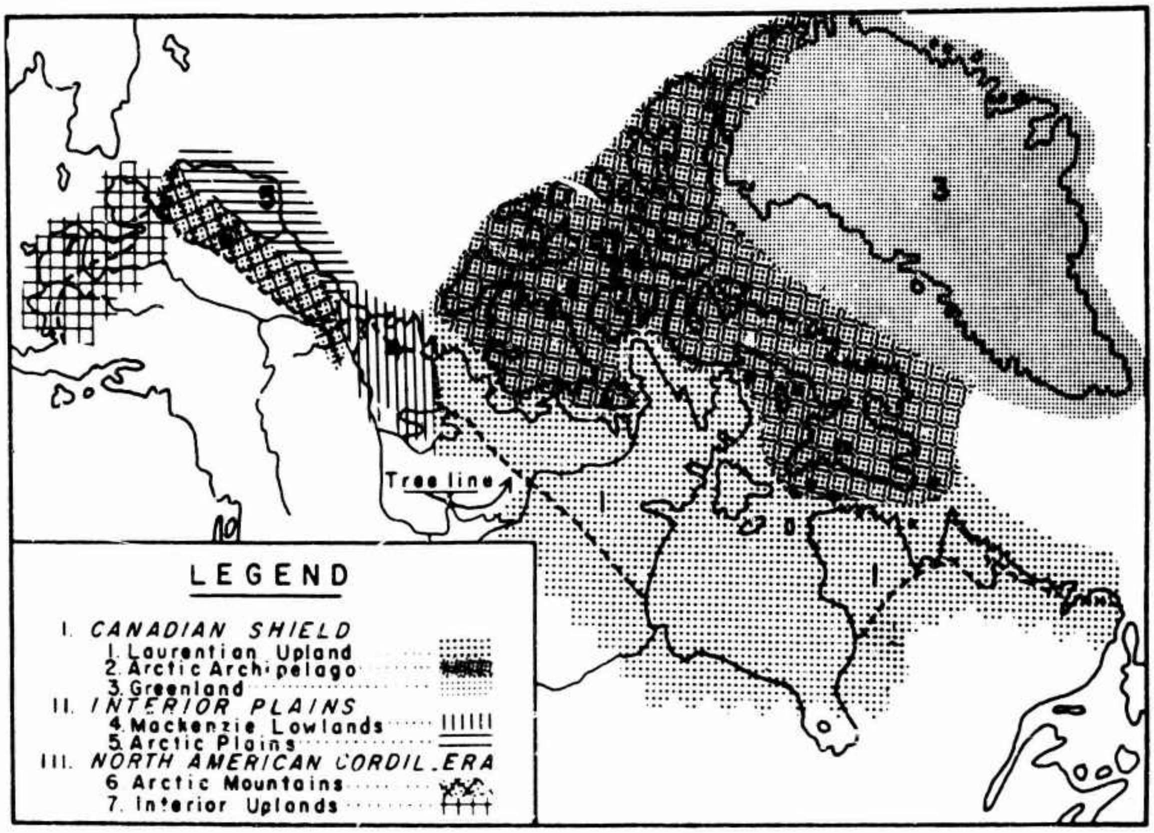


Figure 1. Physiographic regions in the American Arctic. Adapted from Mackay, "Physiography," Geography of *the northlands, ed. Kimble and Good (New York: A G S & John Wiley & Sons, Inc. 1955) chap. ii, p. 12.*

dian Shield is a relatively low rolling plain except in the east where mountains are present. These mountains extend from Ellesmere south through eastern Baffin Island into Labrador. They are also widespread in Greenland.

On the west the Canadian Shield joins the northward extension of the Interior Plains Division at the Great Slave and Great Bear Lakes. This narrow plain, extending north along the Mackenzie River and west along the northern coast of Alaska, is low and flat with poor drainage and numerous lakes and swamps. It, in turn, is bordered on the west and south by the northward and westward extension of the Cordilleran Division, a division which extends to the Bering Sea. This region is characterized by a variety of landforms including the rugged Brooks Range and the low-lying, poorly drained west coast of Alaska.

In the development of the present topography of the Arctic the past geologic history has been important. The most recent widespread effect upon the topography, and one that is still continuing, is glaciation. The land area of the Arctic was covered with ice with the exceptions of the coastal plain of Alaska, the Yukon River drainage area, and probably some of the islands in the Canadian Archipelago. Areas yet covered include some of the highest parts of the eastern Canadian Archipelago islands, favorable locations in Alaska, and about 85 per cent of Greenland.

Those areas formerly covered with ice show the typical features associated with glaciation. Disrupted drainage patterns and numerous lakes are present, as are depositional forms such as moraines and eskers. Ice-scour features are, on the whole, more conspicuous than depositional forms. Widespread raised beaches, which are numerous, indicate recent uplift.

The Climate

The climate of the Arctic is known only in general terms, for records are available from only a few marginal stations. In general, the climate, although variable, has long cold winters, short cool summers, low precipitation, and variable winds.

Temperature. It is the low temperature in the Arctic that gives the extensive snow, ice, and permafrost cover a chance to form and maintain itself, and it is primarily the seasonal changes in temperature that allow seasonal changes in snow, ice, and permafrost. Of the climatic elements, temperature has been discussed more than any other because of the extreme suffering it caused early explorers. Low temperatures have been emphasized.

The lowest temperatures do not occur over the ice pack or at coastal stations, but rather in the interior. In fact, the lowest temperatures in North America are recorded outside the Arctic. Temperatures inland have been recorded below −80° F. It is generally believed that over the sea ice they never go lower than about −60° F., which is also about the minimum recorded at coastal stations such as Point Barrow.

Winter temperatures are not this low on the average. In winter over the arctic pack and the Queen Elizabeth Islands, average temperatures lower than −30° F. occur, as they do in Greenland and the continental interior.[3] The warmest winter conditions are found off the coast of Labrador and southern Greenland because of the presence of open water. Wherever water is in contact with the air in winter, warmer conditions prevail. This condition is quite common in Hudson Strait, Baffin Bay, Bering Sea, and even at leads in the Arctic Ocean itself.

Summer temperatures vary greatly, depending mainly on the surficial characteristics. Over the ocean areas, which are characterized by melting ice, summer temperatures generally remain around the freezing point. Ice-free areas, however, may experience somewhat higher temperatures. Inland stations during summer frequently report quite high temperatures and often record relatively high daily and monthly averages. The absence of a cooling snow cover and the long hours of continuous sunshine are responsible. Coastal stations are intermediate, although coastal temperatures vary greatly during the summer from one year to the next depending upon wind and ice conditions. When the wind holds the ice close to shore through the summer, temperatures—maximum and minimum as well as average—will be lower than normal. Frequently coastal stations will have relatively warm conditions if winds from the interior prevail. The coolest summer conditions are found over the ice cap of Greenland where, even in mid-summer, average temperatures are below freezing.

Wind. Wind in the Arctic, although less important than temperature in its effect on snow, ice, and permafrost, does affect the distribution of snow and ice and the properties of snow. Available wind records, although of short duration and spotty distribution, seem to corroborate the wind patterns derived from analysis of mean pressure distributions.[4]

Such patterns show that during the winter, winds are generally easterly over northern Greenland and northern Alaska and range from northeasterly through northerly to northwesterly over the Archipelago and the Canadian mainland. The winds over Alaska and western Canada tend to be more variable than over central Canada.

During summer, winds with a more easterly component are general. Their variability, however, is greater than for winter winds because local factors become more important with warmer temperatures and because traveling cyclones are more frequent.

Precipitation. The Arctic is not only an area of relatively low temperatures but also one of low precipitation. Climatically most of it is classified as a desert. The actual amount of precipitation varies greatly, ranging from less than five inches to over forty. In the Arctic as a whole most of the precipitation by quantity is in the form of rain falling in the short summer.[5] Summer, which is also the time of snow melt, is the season when nearly all of the precipitation falling in the Arctic is available in liquid form. Probably more important from the standpoint of plant growth than this seasonal character of the precipitation is the fact that permafrost prevents appreciable percolation and low temperature limits evaporation.

There are few areas in which snow accounts for more than half of the total precipitation and even at the North Pole rain furnishes a portion of the total. Although snow is less important than

[3] F. K. Hare, "The climate of the American northlands," *The Dynamic North* (Washington: U. S. Office of Naval Operations, 1956), I, No. 3, p. 15.

[4] S. Petterssen, "Meteorology of the Arctic," *The Dynamic North*, I, No. 2 (1956), p. 35.

[5] In the Arctic rain is not limited to summer, for, near open seas, it may fall during any month of the year.

rain from the standpoint of quantity, it is probably more important in every other way.

Snow, Ice, and Permafrost

Snow, ice, and permafrost, all three of which are characterized by low temperatures and have a similar distribution, may be considered as either climatic or geologic elements. Their formation and seasonality depend to a large extent on various weather conditions, but once formed they become important elements on, in, and of the landscape and, in the Arctic, certainly the most conspicuous as well. Because of this conspicuous nature, snow and ice have been classified along with land and water as one of the three types of surfaces found on the earth.[6]

It has been only within the past two decades that scientists have energetically engaged in the study of snow, ice, and permafrost. Most of this study has been the result of a stimulus provided by a military need for knowledge to operate successfully in the Arctic. Most information published to date is of a preliminary nature and knowledge is still meagre, although some of it is quite fundamental. The following comments are a brief summary of the literature of these three cryological topics. The summary is not all inclusive but is of a general nature emphasizing those factors of greatest significance to the water and food supply aspects of arctic living. Details are frequently added in appropriate sections of the body of the report.

Snow, ice, and permafrost are considered here in that order, an order that is the reverse of their durability. Generally speaking, snow is less durable than ice and ice less so than permafrost. Most of the snow that falls in the Arctic melts during the short summer. Ice, generally speaking, lasts somewhat longer than snow, although lakes and rivers usually have an ice duration approximately the same as that of the surrounding snow cover. Sea ice, on the other hand, may last many years in the Arctic Basin. The oldest ice in the Arctic is glacier ice, some of which may rival most permafrost in age.

Snow. In the Arctic snow is without doubt the most conspicuous feature of the landscape, for it covers both land and sea throughout most of the year. This condition is emphasized by Dunbar and Greenaway who have written that

> Winter in the Arctic lasts from approximately October to April, and winter conditions are those most frequently visible from the air, owing not only to the length of the season but to reduced cloud cover. . . . Snow covers land and sea impartially, smoothing out irregularities and camouflaging landmarks, and there are no trees to give a colour contrast as in more southern latitudes.[7]

Paradoxically, relatively small amounts of snow actually fall in most arctic areas, but most of that which does fall remains throughout the long winter.

The actual amount of snow that falls annually in most of the Arctic is unknown because of the sparseness of recording stations and the difficulties of measurement.[8] Recent snow depth-density studies indicate that reported amounts may be in error as much as 400 per cent.[9] Even though the data are probably erroneous on the low side, it still remains true that most of the Arctic has low annual amounts of snow as well as of total precipitation.

The lowest amounts of snowfall occur probably in the interior of the northeastern islands of the Archipelago and in northern Greenland. Although no measurements are available from these interior areas, coastal stations in these regions, such as Eureka and Thule, have averages of less than fifteen inches. The northern part of the Greenland Ice Cap receives about fifteen inches of snow per year, as indicated by accumulation measurements made along the parallel of 78° N.[10] Dunbar and Greenaway state that ". . . the Arctic Ocean and the low-lying western islands of the Archipelago receive about 25 inches of snow per year."[11] The north coast of Alaska receives between thirty and forty inches as do the south-central islands of the Archipelago. Along the north coast of Canada the snowfall ranges between forty and sixty inches, with a general,

---

[6] E. Espenshade, Jr. and S. Schytt, *Problems in mapping snow cover* (Wilmette, Illinois. U. S. Army Corps of Engineers, Snow, Ice, and Permafrost Research Establishment, 1956), Rept. 27, p. 1. All publications by this organization are identified hereinafter by the abbreviation SIPRE.

[7] Arctic Canada from the air (Ottawa: Queen's Printer, 1956), p. 18.

[8] Snow, usually light and dry in the Arctic, is blown easily. During high winds, it is difficult to determine whether new snow is falling or whether old snow is drifting and standard precipitation gages cannot distinguish the two. Measurement of snow depth is hindered by the wind, which causes uneven drifting.

[9] R. F. Black, "Precipitation at Barrow, Alaska greater than recorded," *Transactions, American Geophysical Union*, XXXV, No. 2 (1954), p. 203.

[10] M. Diamond, *Air temperature and precipitation on the Greenland Ice Cap*, SIPRE Rept. 43 (1956), p. 6.

[11] *Op. cit.*, p. 468.

although slight, decrease inland to the south. Much of the southern part of the Greenland Ice Cap receives comparable amounts, as indicated by studies made at the Mint Julep site in the summer of 1953.[12] Of this amount, about twenty inches is added to the ice surface each year.[13] Still greater amounts fall on the west coast of Alaska, Hudson Bay, southern Baffin Island, Labrador, and southern Greenland. Annual snowfalls of over sixty inches are common and amounts over one hundred inches occur in the more exposed coastal regions.

In most of the Arctic snow may fall during any month of the year, although it is rare during the months of July and August. Nevertheless, Point Barrow averages one inch of snow in July which is more than Thule receives in either January or February. The northern half of the Archipelago generally receives more snow in the summer months than during any winter month.

As the temperature begins to decrease in the fall, snow storms become more frequent, a condition that occurs first in the most northerly parts of the Arctic. In the northern islands of the Archipelago snow storms are frequent in September and some stations have their greatest snowfall then. Farther south in the Archipelago and along the northern coast of Canada and Alaska the month of maximum snowfall is delayed until October, with yet another month delay in those coastal areas where the sea either does not freeze or freezes late in the season. The month of maximum snowfall occurs on Baffin Island, Labrador, and Bering Sea coasts as late as November, December, and even January.

Except for these exposed areas mid-winter snowfall is generally rather light in most of the Arctic, although the wind may cause a great deal of shifting of the snow already on the ground. As spring arrives, with warmer temperatures and higher absolute humidities, snowfall increases to a secondary maximum over most of the Arctic. The amounts falling in March, April, and May are generally not so great as those in September, October, and November, but there are exceptions, especially in the eastern Canadian Arctic where, quite frequently, the month with the second highest snowfall is April.

The number of days during which snow falls, although variable, is generally relatively low. Most of the Archipelago stations have less than sixty days on which it falls with a few averaging less than thirty. As in the case of quantity, the stations at which it most frequently snows are found in the more southerly coastal areas.

In recent years, much attention has been given to the study of the depth of the snow as it varies during the year.[14] Records of actual snowfall are generally not a reliable indication of actual snow depth. Heavy snowfall may be removed rapidly through melting or by wind, in which case a thin snow cover may prevail. Contrariwise, light snowfalls which are additive may result in a relatively deep snow cover.

During the summer, when the snow cover is at a minimum, there are several types of areas which may retain some snow. These include glacier surfaces, high mountains, deep shaded valleys, hills with northern exposure, and, during some years, protected locations on sea ice including the ice islands.[15] The snow that falls in the summer generally melts rapidly and it is not until September that snow may begin to remain on the ground in the more northerly latitudes. By the middle of September most of the sea ice of the Arctic Ocean[16] and nearly all of the islands of the Archipelago have a cover of one inch, a cover that extends over nearly all of the rest of the Arctic by the middle of October. The coastal areas of the Bering Sea and Labrador are exceptions.

Once a snow cover develops, the snow tends to remain, except for wind removal, until the next melt season. Duration varies from seven months in the southern parts of the Arctic to over nine months in the northern islands and on the sea ice of the Arctic Ocean (Figure 2). Once snow melt begins it proceeds rapidly. Snow disappears first from the Mackenzie River basin, including the delta, about the end of May. By the end of June,

[12] E. LaChapelle, "Ablation studies in the Mint Julep area, southwest Greenland," *Project Mint Julep* (Maxwell AFB: Arctic, Desert, Tropic Information Center, Research Studies Institute, Air University, 1955), Pt. II, p. 63.

[13] R. Schuster, "Snow studies," *Project Mint Julep*, Pt. III (1954), p. 7.

[14] Three studies on snow cover are significant: (1) Arctic Construction and Frost Effects Laboratory, *Depth of snow cover in the Northern Hemisphere* (Boston: U. S. Army, Corps of Engineers, 1954). It shows ". . . the average depth of the snow cover in the Northern Hemisphere on the first day of each month, from 1 October through 1 July," p. 1; (2) C. C. Boughner and J. S. Potter, "Snow cover in Canada," *Weatherwise*, VI (1953), 155-59, 170-71; (3) E. Espenshade, *op. cit.*, p. 92.

[15] A. P. Crary, "Arctic ice island, and ice shelf studies, part 1," *Arctic*, XI, No. 1 (1958), p. 16.

[16] An early snow cover on the sea ice is very important in influencing the rate of sea-ice growth.

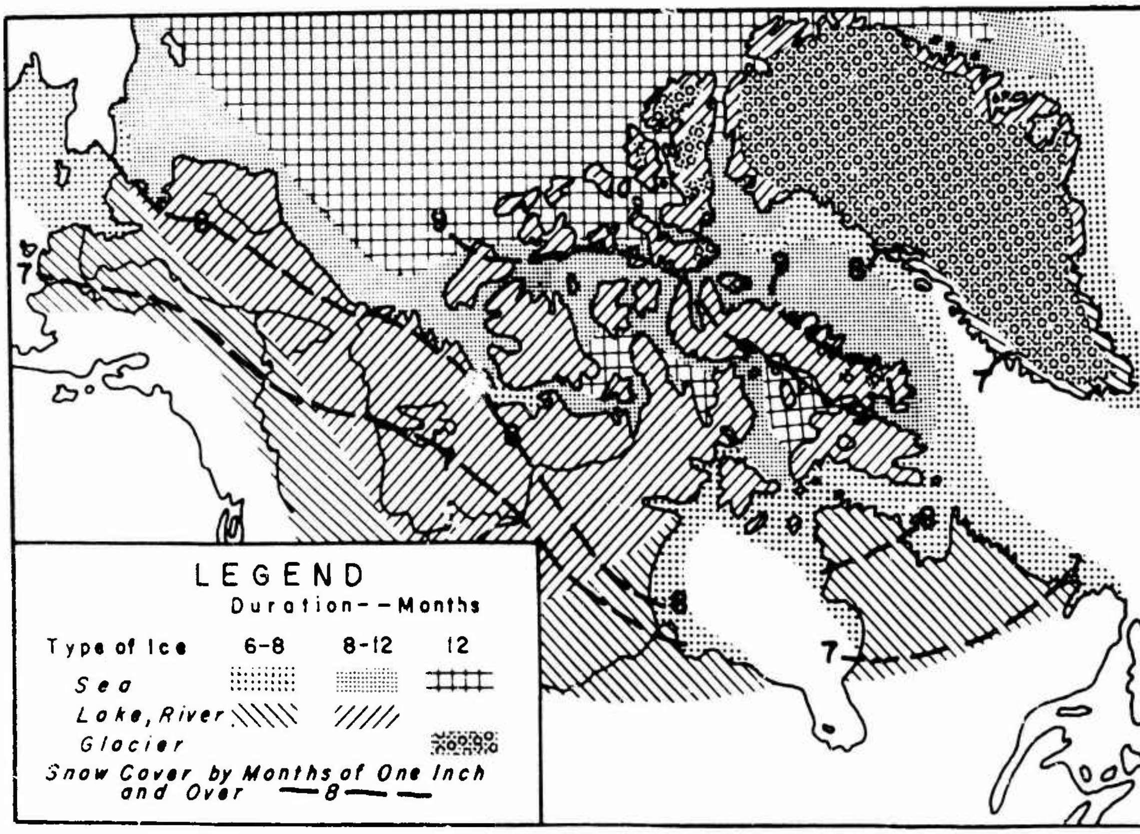


Figure 2. Duration of snow and ice in the American Arctic.

the month of rapid melting, the snow has disappeared from nearly all land areas. Over the arctic pack it may last somewhat longer, although even there snow melting begins by the middle of June.[17]

In the Arctic during ". . . the course of winter the thin autumn layer of snow grows in thickness, almost imperceptibly, . . ."[18] This growth continues until after the spring equinox when a maximum snow depth is recorded. Northern Alaska, the southernmost part of the tundra, Labrador, and Ungava have a maximum depth of snow in March. North of this belt the maximum occurs in April, although the most northerly islands have a maximum in May.

The average depth of snow on the ground during the month of maximum is less than ten inches in the northwestern islands of the Archipelago. Most of the rest of the Arctic has a depth ranging between ten and twenty inches, although the southern part of the tundra is covered by twenty-five inches. Along the west coast of Alaska depths of snow are even greater, as they are in southeastern Baffin Island and Labrador. In these areas ground cover is over forty inches during its average maximum (Figure 3).

As in so many instances, average conditions are not good indications of the true nature of a distribution whether it be temporal or regional. Stefansson wrote that

> . . . most of what little snow falls in the far North is soon swept by the wind into gullies and into the lee of hills, so that from seventy-five to ninety per cent of the surface of arctic land is comparatively free from snow at all seasons.[19]

Deep snow is found only behind rocks and ridges on land and behind hummocks on sea ice. Any surface irregularity furnishes a locus for snow drifts. Near the shore where hummocks are especially numerous snow drifting is extensive. Out

[17] M. M. Somov, *Observational data of the scientific research drifting stations of 1950-1951*, trans. American Meteorological Society (Washington: U. S. Office of Technical Services, 1956), I, sec. 1, p. 11.

[18] Birket Smith, "Geographical notes on the Barren Grounds," *Report of the 5th Thule expedition 1921-24*, I, No. 4 (1943), p. 83.

[19] *The friendly Arctic* (New York: Macmillan Co., 1921), p. 13.

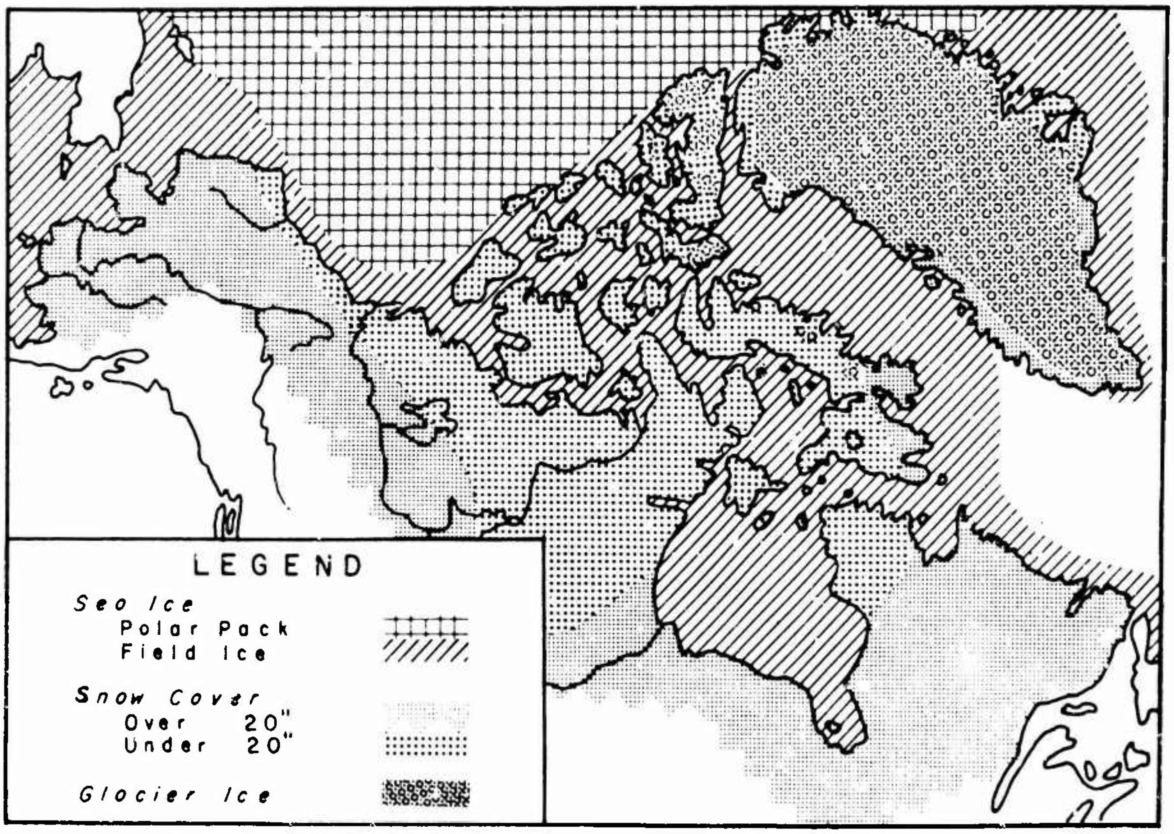


Figure 3. Average snow and ice conditions on 1 March.

on the smooth sea ice, snow accumulates fairly evenly over the surface. In contrast to the rather persistent snow cover on sea ice, lake ice is frequently swept clean (Figure 4). Uneven snow distribution has also been observed on the Greenland Ice Cap. In

> . . . late spring and early summer the deepest snow is in the valleys and lake basins and on the lee sides of the ridges; the thinnest snow cover is on the ridge tops. These differences in snow depth, though small, influence the selection of trails and airstrips during the colder months.[20]

Blowing snow is not only hazardous to many operations in the Arctic but is also important as a relief modifier. Relief on the already relatively flat surface most common in the Arctic is further reduced as the snow drifts into the valleys and fills them. Although patches of lake ice may be free of snow, near the shore drifting is usually heavy and the shape of lakes is difficult to discern from the air. The same condition prevails at the sea ice-land boundary.

On the snow surface itself, surface features are formed by the wind. The well known sastrugi are the most conspicuous forms. This term frequently includes all snow-surface forms resulting from the scouring and filling action of the wind. These forms vary greatly in shape with variations

[20] G. W. Holmes, "Morphology and Hydrology of the Mint Julep Area, Southwest Greenland," Project Mint Julep, Pt. II (1955), p. 47.

Figure 4. Lake ice from which snow has been partially cleared by the wind.

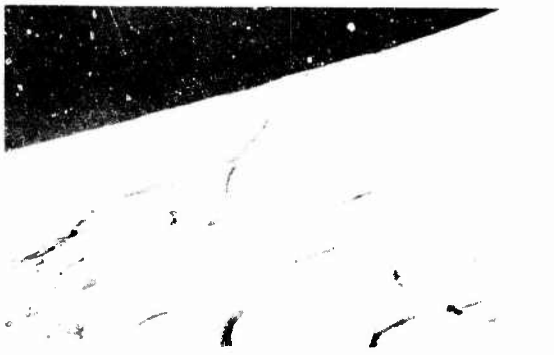


Figure 5. Snowdrift after snowslide, illustrating wind compaction.

in velocity and direction of wind and in snow properties.

Snow drifting and wind packing (Figure 5), by filling up hollows, smoothing out surface irregularities, and hardening the snow cover, bring many advantages to man. The most important are probably the creation of ready transportation routes and landing surfaces, furnishing of a building material, and a source of water supply.

Although snow is the most common type of solid precipitation in the Arctic, there are several others that add to the total, including sleet, rime, hoarfrost, ice needles, and glaze. Some of these, especially hoarfrost, occasionally contribute significant amounts in the low-total precipitation areas.[21]

Snow varies greatly in character during the different seasons. Somov, for example, observed at his ice-floe station that,

> In the spring period, the solid precipitation consisted chiefly of hexagonal snowflakes, during the warm season, of granular snow, and sometimes (as, e.g., on 20 December) trigonal snowflakes fell.[22]

Because of the variety of precipitation types and of snow forms which may enter into a snow cover, its properties are highly variable.

> Snow may be an elastic body like ice, or a highly brittle or fragile substance, as granular snow, or a substance which may be considered a true powder, as cold powder snow. Therefore, when studying the nature of snow, a wide range of properties must be considered.[23]

Snow properties include density, hardness, strength, waterholding capacity, porosity, crystal size and shape, among others. Probably the most important physical properties of a snow cover are its density and hardness.

Both density and hardness vary regionally and seasonally and may also vary vertically and horizontally within a given snow cover. Freshly fallen snow has an initial density that varies with snowflake size.[24] With settling and packing, density increases and the longer it remains, the denser it becomes.[25] Although such pressure is the first cause of density increase, it accounts for only a relatively small increase. Even after settling, the density of a fresh small-flake snow cover is less than 0.2.[26]

Increases in density beyond these initial amounts are brought about in a variety of ways. Wind is considered one of the most important. M. A. Bilello, for example, found that ". . . high snow densities frequently were associated with strong winds and low densities with light winds."[27] Wind not only crumbles snowflakes in the air such that they can be forced into air spaces in the snow but it also uses them in bombarding the windward surface of a snow cover packing it.[28] In this process, however, wind creates a wind slab that protects the lower layers from further bombardment (Figure 5). Subsequent snowfall and windstorms result in creating a series of layers of varying densities, densities which are affected by other factors including crystal growth,[29] the addition of melt water, and compression resulting from alternating frost and thaw weather.

Hardness, like density, is affected by wind and temperature, a fact reported by K. R. Koch in 1895.[30] As wind speed increases, hardness likewise increases. Records collected in the past few years on density and hardness of snow cover at the various weather stations in Arctic America show that there are seasonal and regional differences. These differences are not yet well documented but in general show that density and hardness increase as winter progresses and that they are

[21] G. D. Rikhter, *Snow cover, its formation and properties*, SIPRE trans. 6 (1954), p. 7.

[22] *Op. cit.*, III, sec. 8, p. 6.

[23] T. Takahashi and K. Kudo, Hardness test of snow, SIPRE trans. 40 (1955), p. 4.

[24] N. G. Dmitrieva, *Calculation of snow-cover density using meteorological data*, SIPRE trans. 24 (1954), p. 1.

[25] Rikhter, *loc. cit.*

[26] Dmitrieva, *loc. cit.*

[27] *A survey of arctic snow-cover properties as related to climatic conditions*, SIPRE Rept. 39 (1957), p. 6.

[28] Rikhter, *op. cit.*, p. 6.

[29] A. Taylor, *Snow compaction*, SIPRE Rept. 13 (1953), p. 5.

[30] Hardening of the snow through wind, abstract, SIPRE bibliog. X, p. 37.

higher in the Canadian Archipelago than on the mainland of Canada or Alaska.[31]

Ice. If it was not for the snow that mantles the surface of the Arctic throughout most of the year, ice would be the most widespread surface form. It covers nearly all of the lakes, rivers, and ocean for much of the year; indeed, most or all of the year in much of the Arctic.

As in the case of snow, ice may be an asset or a hindrance. It not only hinders but, in nearly all of the Arctic, completely halts all water transport. At the same time, however, it may prove of great benefit to surface and air transport through the formation of natural roadbeds and landing fields (Figure 6). Frequently of great importance is the fact that ice allows reduction of travel distance between two points. Lakes, which during the thaw season make circuitous routes necessary, present a solid surface during winter. Therefore, the time of freeze-up and thaw are significant in the Arctic. Ice is indirectly quite important in climate. By separating water surfaces from the atmosphere, ice tends to give continental characteristics to much of the Arctic that otherwise would be maritime.

Ice in the Arctic may be considered for convenience under the following categories:

Lake and River Ice
Glacial Ice
a) Ice Caps
b) Icebergs
c) Ice Islands
Sea Ice

Lake and River Ice. A large portion of the land area in the Arctic and Subarctic is covered by lakes and rivers which freeze during the cold season. The exact percentage of the land area covered by fresh water in the summer and fresh-water ice in the winter has never been accurately calculated, but it is high in comparison with other parts of the world.

In regions described as flat, lakes cover on the average about 40 per cent of the area, although in many regions the amount may be as much as 90 per cent.[32] In the hilly and mountainous sections of the Arctic, lakes are less common. Lakes vary greatly in size; some are among the largest in the world such as Great Slave Lake and Great

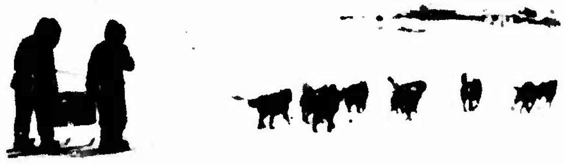


Figure 6. Smooth surface of snow-covered lagoon being used as a road. This lagoon is also used as a landing strip.

Bear Lake. Most, however, are quite small and, in the glaciated areas, quite irregular in shape.[33]

Rivers and streams are also numerous in the Arctic. Many are connections of the numerous lakes and are short, containing many rapids and falls.[34] Some of the rivers, such as the Mackenzie and Yukon, are long and carry much water to the ocean. Their discharge is not great, however, when compared with the large rivers in the temperate and tropical areas of the world. Many of the streams, especially in the northern islands are dependent on snow melt and are thus dry except for a short period of time during the melt season. These streams are dry during the period of freeze-up and therefore do not have river ice in the winter.

The time when lakes and rivers freeze in the Arctic is about the same as when the snow begins to remain on the surface, although the largest lakes and the fastest and more voluminous rivers remain open somewhat longer. There are some rivers, such as those leading from many of the lakes in the Mackenzie Delta and Back River, which have stretches that never freeze. In the Archipelago lakes begin to freeze in August and on the mainland in September, although the mainland lakes generally do not become completely covered before October.[35] Snow falling during freeze-up tends to blanket the area, but much of the river and lake ice, being relatively smooth, remains snow free because of wind clearing.

The period of ice cover on lakes and rivers varies, but most of the Arctic has a cover lasting

[31] Bilello, *op. cit.*, p. 4.
[32] M. C. Brewer, "The thermal regime of an arctic lake," *Transactions, American Geophysical Union*, XXXIX, No. 2 (1958), p. 278.
[33] U. S. Office of Naval Operations, *Canadian North*, Chap. ii, p. 54.
[34] *Ibid.*, intro., p. 10.
[35] Dunbar and Greenaway, *op. cit.*, p. 18.

eight months or more (Figure 2). The only parts of the Arctic which have river and lake ice for less than eight months are the Bering Sea coastal areas of Alaska, southern Greenland, and the Ungava-Labrador region where the ice breaks up somewhat before the middle of June.

In the northern Archipelago the general duration of freshwater ice approaches ten months, although occasionally ice remains in some of the larger lakes throughout the summer, especially in cool summers. Floating ice may remain in lakes long after breakup, especially in those lakes with small outlets.[36]

Although fresh-water ice begins to form at about the same time as snow cover, it does not disappear so soon. Usually ice will remain two to four weeks after the bulk of the snow has melted providing a great contrast in the appearance of the landscape during the first part of the summer. The season of melting lasts from four to six weeks, although it varies greatly with such factors as river and lake size and depth.

The thickness of the ice in lakes and rivers has only recently been studied. It was not until the need for landing aircraft on ice became an important phase of military aviation that systematic study of ice thickness was begun. Ice thicknesses appear in many of the journals of explorers but they are probably never maximums, as the intent of the explorer was to get through the ice to the water beneath and the natives who almost always did the digging would choose locations where the ice was thinnest.[37] Factors affecting such thickness include not only temperature conditions but also the snow cover, which acts as an insulator, depth of the water, wind conditions, and velocity of the water in the case of rivers.

As most lakes, especially the small ones, are shallow, they freeze to the bottom during the winter. The thickness of the ice on lakes and rivers which do not freeze to the bottom probably seldom exceeds eight feet,[38] a value used in water supply recommendations for the DEW Line.

[36] Canada, Department of Mines and Technical Surveys, Geographical Branch, "The Canadian Arctic," *Canadian geographic information series*, No. 2 (1951), p. 34.

[37] J. Ryder, *Compilation and study of ice thicknesses in the Northern Hemisphere* (New York: American Geographical Society, 1954), p. 7.

[38] A. Alter, "Water supply problems in low temperature areas," *Selected papers, Alaskan Science Conference 1950*, p. 223. Brewer writes that, "Lakes more than six to seven feet deep do not freeze to the bottom . . .", "The thermal regime of an arctic lake," p. 278.

Glacial Ice. At one time most of the Arctic's land area was covered with ice,[39] although today it is mainly free of this over-burden. Today glacial ice has a restricted distribution, being found only in Greenland, on the islands west of Kane Basin and Baffin Bay, and to a limited extent on the northern slope of the Brooks Range (Figure 3).[40]

The size of individual glaciers varies from small snow-filled valleys of Ellesmere to the inland ice sheet of Greenland which covers nearly two-thirds of a million square miles. The ice cap of Greenland varies in general from 5,000 to 10,000 feet in elevation. It has been described as a ". . . remarkably smooth and gently rolling snow-covered plateau which conventional oversnow vehicles can cross with ease, . . ."[41] Although it does not have a completely symmetrical dome, it does have gentle slopes extending down from a crest at rates varying from five to fifty feet per mile.[42] This slope continues to the edge of the ice sheet where the ice is relatively thin and where many nunataks occur. Although there is an almost continuous ice-free zone around the coast, ice reaches the sea in many places. About one-tenth of the ice of Greenland is separated from the main mass of ice and occurs in the form of independent ice bodies.[43]

In the Canadian Archipelago, which contains about 60,000 square miles of glaciers, are found several ice caps as well as alpine glaciers.[44] Some glaciers extend to the coasts, although others terminate before reaching the sea. The mainland of Canada and Alaska has relatively few glaciers and nearly all of these are outside the Arctic. There are a few small alpine glaciers in the Brooks Range, Mackenzie Mountains, and the mountains of Labrador.

Ice from glaciers on reaching the coast breaks off, becoming icebergs. The icebergs of the Arctic are nearly all restricted to the water surrounding Greenland, originating on both sides of Greenland as well as in the islands of the Canadian

[39] Exceptions are found on the arctic slope of Alaska and probably in parts of the Canadian Archipelago.

[40] R. Sharp, "Glaciers in the Arctic," *The dynamic North*, I, No. 7 (1956), p. 13. Of the .87 million square miles of glaciers in the Arctic and Subarctic of the Northern Hemisphere, about 95 per cent are found in North America. Distribution in North America is similar in that Greenland contains about 88 per cent of the total with the Canadian Archipelago and continental North America having 7.5 and 3.5 per cent respectively.

[41] P. Nesbitt, "Introduction," *Project Mint Julep*, Pt. 1 (1955), p. 5.

[42] Sharp, *loc. cit.*

[43] *Idem.*

[44] *Ibid.*, p. 32.

Archipelago. Although icebergs are found in Greenland waters throughout the year, there is a seasonal variation in their occurrence and movement. During the cold season many are anchored in the winter ice along the coastal areas. Normally they float south and become entrapped in the Labrador Current to be carried out into the Newfoundland Banks region.

Within eight years following 1946, when the first ice island was recognized [45] on a radar scope, over sixty ice islands had been located within the Canadian Arctic. Of these, about 75 per cent were among the islands of the Archipelago, the rest in the Arctic Ocean.[46]

The size of these ice islands which are believed to have originated on the north coast of Ellesmere Island,[47] varies up to 200 square miles in area. Crary and Browne write that, "The total ice island area is about 1,000 square miles, with most of this made up by the four largest islands."[48]

These islands, which are comparable to the tabular icebergs in the seas around Antarctica, are relatively flat and may be as much as 200 feet thick. They are quite stable when compared to the general ice pack which is in almost constant motion and they are durable as long as they remain in the Arctic.

Although they are usually referred to as flat, some of these islands have a ridge and valley type surface with a local relief of two to five feet on the average. As the islands are snow covered most of the year, troughs are not obvious features. During the two month melt season, however, these troughs, being filled with water, stand out.[49] During summer numerous lakes are present, lakes that are connected by streams which eventually drain to the sea.

The importance of these islands as scientific stations stems not only from their relative permanence and stability but also from their movement around the ocean. This movement is affected by many factors including wind, ocean currents, the island's thickness, ocean depths, and the relationship existing between the ice island and the surrounding ice pack. Although the rate of movement is quite variable, T-3 (Fletcher's Ice Island) averaged about one nautical mile per day in its nine-year circuit.[50]

Sea Ice. In arctic waters are found several types of land-derived ice including river ice, icebergs, and ice islands. By volume and surface coverage these form a very small percentage of the total and, with the exception of ice islands, are almost never found in the central part of the Arctic Ocean. The bulk of the ice in the seas of the Arctic is sea ice.

Sea ice distribution varies greatly from one season to the next. During March, when sea ice is at its maximum extent, it reaches south to about 60° N. in the Bering Sea, and to James Bay and Newfoundland. The only area relatively free during this season is the southwest coastal area of Greenland (Figure 3). In summer nearly all of the coastal areas are free of ice and it is restricted to the Arctic Basin except in some of the straits in the Archipelago and along the northern coast of Greenland (See Figure 16). Such ice-free conditions are of short duration. Only Hudson Strait, Hudson Bay, the Alaskan coast south of Bering Strait, and most of the coasts of Greenland south of about 75° N. are free of ice for more than four months of the year (Figure 2).

Several factors affect the time of ice formation and of ice breakup. Among the most important, besides temperature conditions, are the size, depth, and shape of coastal indentations and straits, direction and strength of winds[51] and ocean currents, fresh water drainage from land areas, and tidal conditions.[52]

For man, one of the most important zones of ice formation is along the shore. Numerous factors influence the character of shore ice including winds and tides. Areas with low tides and little wind usually develop a wide, smooth sea-ice cover

[45] Ice islands, although possibly not recognized for their true nature, were observed and used by explorers prior to 1946. It is believed that G. W. deLong in 1881 crossed over one and that Storkerson in 1918 used one as a floating base for six months. See Moira Dunbar, "Historical references to ice islands," *Arctic* V, No. 2 (1952), p. 88.

[46] Crary and Browne, *Probable ice island locations in the Arctic Basin, January 1954* (Cambridge, Mass.: Air Force Cambridge Research Center, 1954), No. 50, p. 1.

[47] I. S. Koenig, et al., "Arctic ice islands," *Arctic* V, No. 2 (1952), p. 67.

[48] *Op. cit.*, p. 2.

[49] Crary, *op. cit.*, p. 7.

[50] H. Sverdrup, "Arctic sea ice," *The dynamic North*, I, No. 6 (1956), p. 1.

[51] Stefansson in *My life with the Eskimo* (New York: The Macmillan Co., 1951) emphasized the importance of wind as it affects ice conditions along the coast of Alaska near Point Barrow as follows: "The spring [1908] had been an early one, so far as the disappearance of snow from the land was concerned, but after all, temperature has practically nothing to do with navigability of the Arctic Ocean north of Alaska. It is entirely a matter of the prevailing winds. When westerly winds blow, the ice is blocked solidly against the land, while with easterly winds the ice goes abroad, leaving no obstructions to navigation. Four years later, in the summer of 1912, I saw the Polar Sea west of Point Barrow apparently as open as the Atlantic off Sandy Hook,—in spite of the fact that the summer of 1912 was the coldest of thirty years." p. 47.

[52] J. Jenness, "The Physical geography of the waters of the western Canadian Arctic," *Geographical Bulletin*, No. 4 (1953), p. 46.

Figure 7. Rough shore ice in Frobisher Bay.

with relatively few hummocks—a type especially good for use as a roadbed (Figure 6). In contrast, high tides and winds result in the formation of a rough surface near the shore (Figure 7). The time of freeze-up is also important, for, if it comes during a calm period, the ice will be smooth; whereas, if during a stormy period, it will be rough.

Many methods of classifying sea ice have been used, including that of the U. S. Hydrographic Office based on navigability. A somewhat more recent classification, based on the regions of origin, has been summarized by Moira Dunbar. In this classification, ice in the American sector of the Arctic Ocean is considered as belonging in four groups: North Pole, Paleocrystic, Baffin Bay, and East Greenland.[53] For purposes of this study three additional sea-ice groups are added; namely, Hudson Bay, Canadian Archipelago, and Bering Sea (Figure 8).

The North Pole ice region, extending from Greenland across the pole to the north coast of Alaska, is made of ice that is mostly old (85 per cent according to Corton [54]); the rest is winter ice. Winter ice forms in the many openings and leads that occur in the polar pack, even in the center of the Arctic Ocean. These leads are temporary in the winter, freezing over rapidly once formed. In contrast, summer leads do not freeze but remain open until the fall unless closed by ice drift.

The thickness of North Pole ice varies greatly from the relatively thin winter ice in undeformed leads to the thick ice found in pressure ridges. Winter ice, formed under severe temperature conditions and little or no insulating snow cover, may be as much as ten feet thick.[55] T. Armstrong writes that, "In general, thickness tends to increase with latitude, . . . But many exceptions to this tendency have been found."[56] Polar ice has a thickness that depends on the relationship that exists between winter freezing, summer melting, and hummocking. Thickness will range generally from about a maximum of twelve feet for unhummocked floes [57] to a maximum approaching sixty feet in pressure ridges.[58]

Pack ice is made of ice of various ages.[59] Wind and currents are important, for under their influence". . . the ice is constantly drifting and material of various ages may intermingle, giving rise to a unique mosaic of ice or different age and shape."[60] As a result of the pressure the ice sheet has a variety of relief features. According to Peschansky, "One of the most important factors in an ice field is its surface, . . ."[61] a surface that is quite irregular during all seasons of the year. It is criss-crossed by pressure ridges and by open or newly frozen leads both of which generally run in all directions because of the variability of the winds.[62] These ridges are formed primarily through the buckling of relatively weak young ice.[63]

During winter sea ice is generally covered with snow—relatively thin on the smooth areas but quite thick in the lee of hummocks and ridges. During the two or so months of summer when the snow and some of the ice melt, the ice surface contains numerous thaw pools. Melting rounds off hummocks and forms depressions. The ice floe upon which the U. S. drift station *Alpha* was lo-

[53] "Water masses, circulation, ice cover," *Geography of the northlands*, ed. Kimble and Good (New York: American Geographical Society and John Wiley & Sons, Inc., 1955), chap. III, p. 51.

[54] "A study of the arctic ice pack," *Transactions, American Geophysical Union*, XXXV, no. 2 (1959), p. 375.

[55] Sverdrup, *op. cit.*, p. 13.

[56] "The ice of the central Polar Basin," *The Journal of Glaciology*, III, no. 22 (1957), p. 108.

[57] N. Untersteiner and F. Badgley, "Preliminary results of thermal budget studies on arctic pack ice during summer and autumn," *Arctic sea ice*, ed. W. R. Thurston (Washington: National Academy of Sciences-National Research Council, 1958), sec. 3, p. 91. They also write that ". . . everywhere in the Arctic Basin the [illegible] heat supply during a part of the summer is sufficient to [illegible] the recent snow cover and a certain amount of solid ("old") ice. When the annual amount of accretion equals the summer ablation, then the pack ice has reached its stationary thickness." p. 91.

[58] Sverdrup, *loc. cit.*

[59] I. S. Peschansky, "Physical and mechanical properties of arctic ice and methods of research," *Arctic sea ice*, p. 103. Peschansky reports that the floe on which NP-4 was located had existed nine years when the study was begun in 1955. "The upper (active layer) was in the tenth year. The age of polar ice is a relative matter and may be determined only for the given moment, as the process of melting of the upper ice surface and the growth on the lower surface is going on constantly." p. 103.

[60] A. A. Kirillov, "Classification of arctic ice and its distribution in the Soviet sector of the Arctic," *Arctic sea ice*, sec. 1, p. 12.

[61] *Loc. cit.*

[62] Sverdrup, *op. cit.*, p. 12.

[63] Kirillov, *op. cit.*, p. 13.

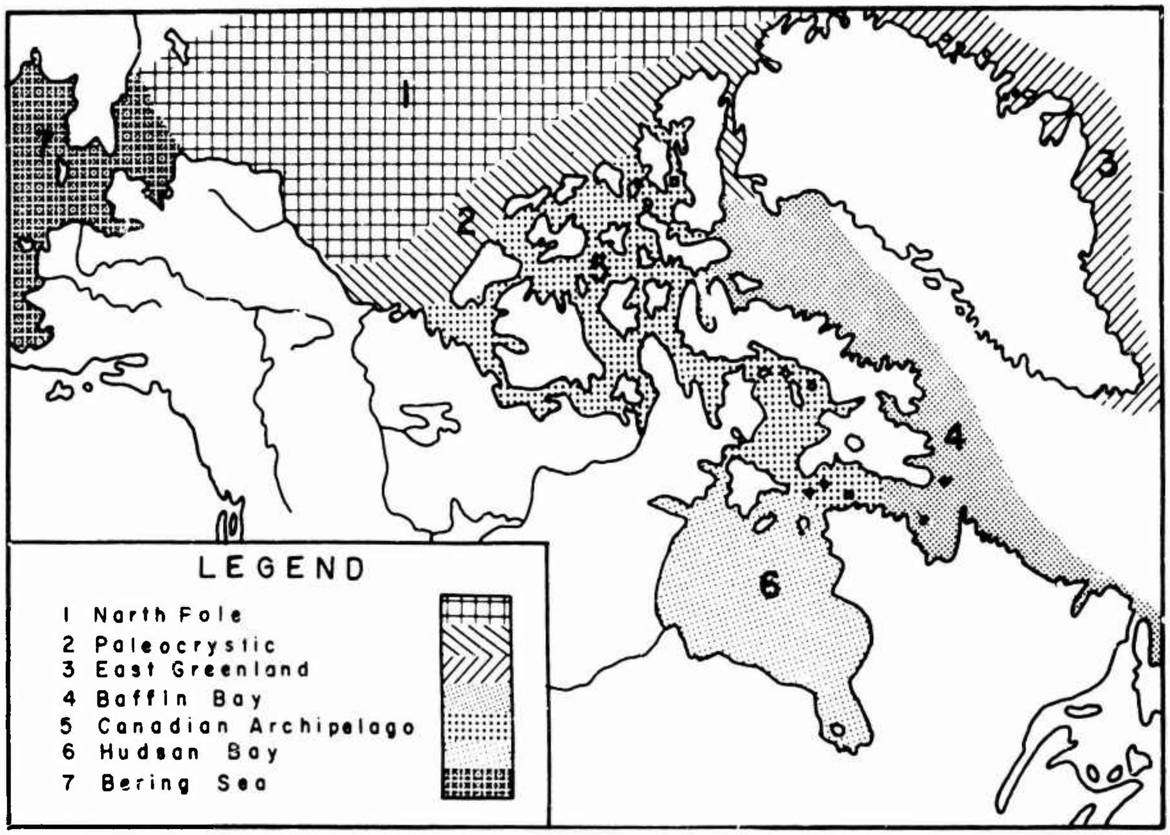


Figure 8. Sea ice types in the American Arctic. Adapted from Moira Dunbar, op. cit., *p. 51.*

cated had an estimated cover of melt water amounting to 30 per cent in July, 1957, when it was at 82° N.[64] During the drift of the Fram the crew" . . . amused themselves by sailing boats on the lakes which formed in summer on the ice fields."[65]

Surface water is very important in the thermal regime of an ice pack, for it reflects less of the incoming radiation than either snow or ice and thus speeds up the melting rate. Increased melting in ponds creates holes in the ice through which the ponded fresh water drains. This fresh water, with a higher freezing temperature than the sea water beneath the ice, freezes to the bottom of the sea ice.

[64] Untersteiner and Badgley, *op. cit.*, p. 89.

[65] N. N. Zubov, *Arctic ice and warming of the Arctic*, trans. E. Hope (Ottawa, Canada: Defence Research Board, 1950), p. 15. Some of the ponded water that occurs around camps on sea ice results from man's presence. Somov, in commenting on the Russian Station North Pole 2, notes that, "An especially large amount of melt water accumulated in the camp area, when large snowdrifts had amassed during spring months, and whose weight had caused a considerable sag basin in the ice. Furthermore, the soiled surface of the snow and ice in the camp accelerated thawing." *Op. cit.*, I, sec. 1, p. 11.

Paleocrystic ice occurs in the buffer zone between the North Pole ice and the Canadian Archipelago. This ice, although separated from the North Pole ice by great leads in summer, is primarily made of old polar ice. It differs from the ice of the Polar Basin in being older, thicker, and much rougher. It is in this belt that most of the ice islands have been observed. Virtually none of this ice penetrates between the islands of the Archipelago except through McClure Strait.[66]

East Greenland ice comes primarily from the Arctic Ocean, although it also contains locally formed ice including icebergs. Ice from the Arctic Ocean is carried south by the East Greenland Current after it has reached the southeast portion of the polar pack. This southward-moving ice is a continuous phenomenon such that the northern and central coast off east Greenland is nearly always ice bound. The width and length of the belt change with seasons. During the winter ice reaches around Cape Farewell and extends as far

[66] J. Jenness, *op. cit.*, p. 47.

north on the west coast of Greenland as Ivigtut. The ice itself is ". . . usually broken and rafted into innumerable heavy floes of various sizes with a thickness often 20 to 30 feet."[67]

Baffin Bay ice is formed in Baffin Bay itself and in some of the sounds to the west thereof. In general, the movement of this ice is toward the south carried by the Labrador Current. Baffin Bay ice is younger than the North Pole ice.[68] Baffin Bay ice on the whole is not so thick as the ice found in the other areas. It contains many icebergs which have been discharged from glaciers on both sides of the bay.

Dunbar and Greenaway have written that

> All the waters of the Canadian Arctic are ice-covered for all or part of the year. The amount and duration of ice cover, however, varies considerably, increasing not, as might seem natural, from south to north, but generally from south-east to northwest.[69]

The sea ice found in the straits of the Archipelago is quite variable because of a variety of origins. In many areas, as in Amundsen Gulf and Simpson Strait, the only ice present forms *in situ* and all of it melts during the next thaw season.

The other extreme is found in such areas as Hecla and Griper Bay where ice remains throughout the year.

> Some of these bodies of ice may become largely covered with water on their surfaces, and may even partly break up in certain instances, but because there is no way for the ice to disappear other than in melting in situ, the essential characteristics of a total covering is retained.[70]

In addition, there are areas in the Archipelago where locally formed new ice and old ice, much of which has been brought into the straits by winds and currents, occur together.

Hudson Bay, the most southerly part of the Canadian Arctic seas, was believed to be partly ice free throughout the winter until recently. It is now known, however, that the entire bay freezes. The pack is almost all winter ice, although it does contain some sharp and jagged pressure ridges. It averages less than most arctic pack ice in thickness, being only three to six feet.[71]

Bering Sea is somewhat comparable to Hudson Bay in that the ice in it is almost all entirely new each year. In the northern part of the sea the bays have ice forming as early as October after which the amount gradually increases, spreading southward.

Sea ice has certain physical and chemical characteristics which are of great importance to man in the Arctic. The first ice crystals formed in ocean water are pure ice, but, as they continue to form, salt water is trapped and, as the temperature lowers, it also freezes. "Thus, sea ice is formed which consists of pure ice containing numerous small cavities filled by brine."[72] As the amount of brine trapped is mainly dependent upon the rate of freezing, sea ice is variable in salt content.

It is a well-known fact that as sea ice ages its salinity decreases. This change is believed to result because the temperature at which water freezes varies with salinity. Fresh water freezes at a higher temperature than saline water. If a temperature gradient exists in the ice, brine will migrate in the direction of the higher temperature. Thus, during most of the year it will migrate downward, as the water temperature beneath the ice is higher than the air temperature above it. As a result some sea ice is practically fresh.[73]

The salt content, incorporated air bubbles, and temperature of sea ice affect its physical properties. Generally, the fresher the ice the more valuable it is to man, not only as a source of water but also because it possesses more desirable physical properties.[74]

Permafrost. The paucity and recency of permafrost research belie its significance to man in the Arctic, for its direct and indirect effects are great. It has to be considered in the development of water supply and sanitation systems, construction of buildings, highways, and airports, and in mining and agricultural pursuits. Although generally considered as one of the environmental hindrances to be overcome in the Arctic, permafrost may be used to advantage in natural cold

[67] U. S. Hydrographic Office, "Arctic ice and its drift into the North Atlantic Ocean," *Pilot chart 1411* (14th ed.; Washington, D. C., 1955), p. 1.
[68] Maxwell Dunbar, *op. cit.*, p. 51.
[69] *Op. cit.*, p. 418.
[70] J. Jenness, *op. cit.*, p. 4?.
[71] Dunbar and Greenaway, *op. cit.*, p. 418.

[72] Sverdrup, *op. cit.*, p. 6.
[73] *Ibid.*, p. 8. Although the exact physical process by which sea ice freshens is debated, several factors affecting this process are agreed upon and include (1) the original salinity of the water, (2) the temperature at time of formation, and (3) the age of the ice.
[74] I. Tabata, "Studies on visco-elastic properties of sea ice," *Arctic sea ice*, sec. 3, p. 139. Tabata illustrates one such advantage when he writes that ". . . fresh water ice of 3 to 4 cm thickness is strong enough to skate upon, while it is barely safe to walk upon sea ice of 10 cm thickness." p. 139.

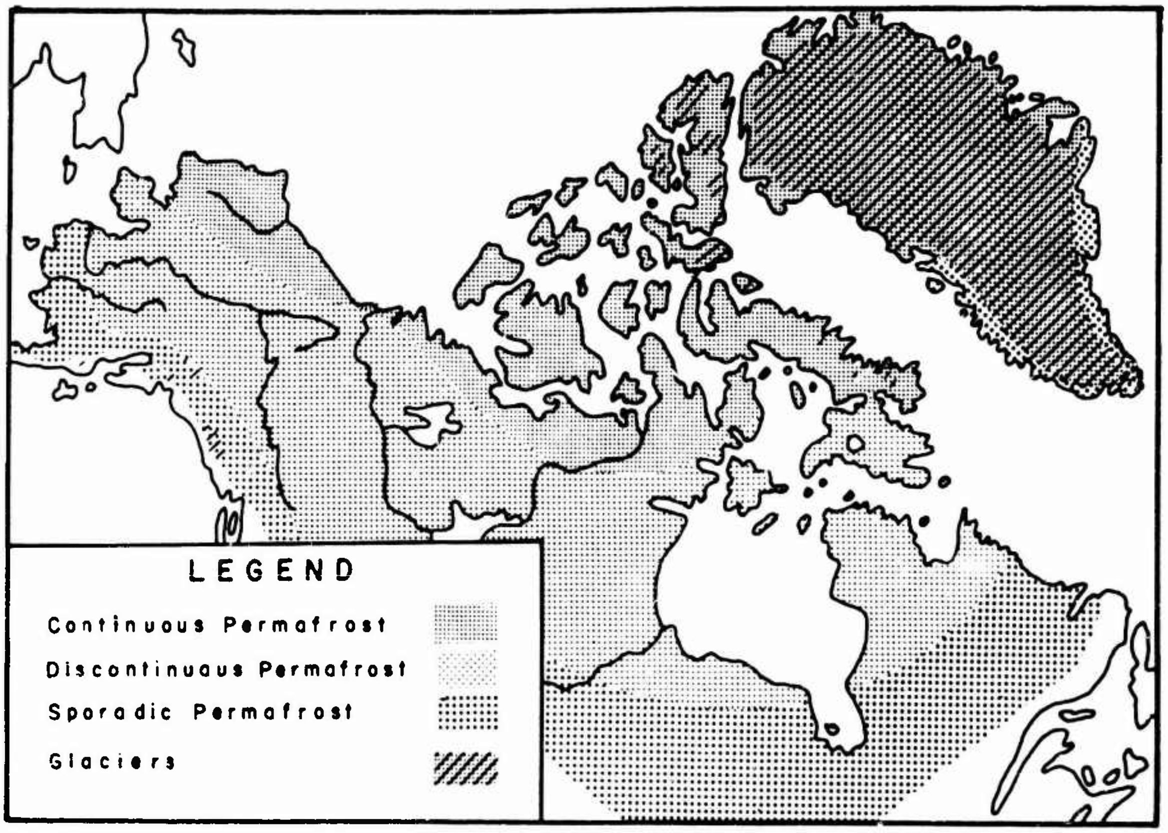


Figure 9. Permafrost distribution in North America. After Black, "Permafrost as a natural phenomenon," p. 4.

storage, cross-country transportation, and many types of construction.

Permafrost, which underlies to varying depths about 26 per cent of the world's land area,[75] is, as stated by Troy Pewe, "Perhaps the most common result of long cold winters and short summers. . ."[76] Other conditions favoring permafrost formation include low annual rainfall and snowfall, cloudless winters and cloudy summers, rapid evaporation, cold winds, and low insolation.[77]

Permafrost, found as far south as 50° N. in North America and Asia, varies greatly in concentration and depth. Because of such variations it has been areally subdivided into three belts: continuous, discontinuous, and sporadic, the distributions of which are known only generally (Figure 9). In the continuous zone permafrost, found everywhere except under large bodies of water, is normally quite thick, with depths of 1,300 feet in places, and has a shallow active layer (Figure 10). In the discontinuous zone permafrost does not possess the continuity nor the depth found in the continuous zone and it also has a thicker active layer. The sporadic zone is characterized by scattered permafrost only. The area of concern in this study lies almost entirely within the continuous permafrost zone. Exceptions occur along the west coast of Alaska, the areas around Hudson Bay and Hudson Strait, Labrador, and southern Greenland (Figure 9).

Permafrost characteristics of significance to man include its temperature, ice content, and thickness of the active layer. Although the temperatures in the upper levels of permafrost vary seasonally, they do not reach the low temperatures of the atmosphere. The snow cover during winter insulates the frozen ground beneath.

[75] R. Black, "Permafrost: A review," *Bulletin of the Geological Society of America*, LXV (1954), p. 839.

[76] "Permafrost and its effect on life in the North," *Arctic Biology—Biology Colloquium*, ed. H. P. Hansen (Corvallis: Oregon State College, 1957), chap. iii, p. 12.

[77] Black, "Permafrost as a natural phenomenon," *The Dynamic North*, II, No. 1 (1956), p. 12.

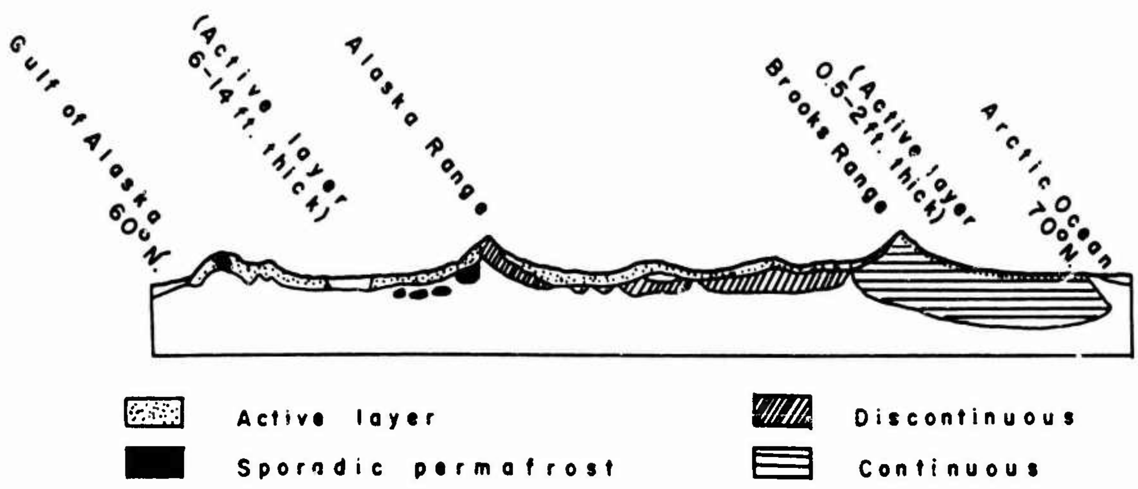


Figure 10. Approximate distribution of permafrost across Alaska. After Black, "Permafrost as a natural phenomenon," p. 4.

Although, as defined by S. W. Muller, permafrost does not necessarily involve water and therefore ice, most permafrost is nevertheless, consolidated by ice.[78] This ice, occurring in various sizes and shapes, has been considered as ". . . probably the most important feature of permafrost affecting life in the north."[79] Pewe has grouped ground ice into the following three main types:

> (1) interstitial ice and small segregations of ice that grow as the ground becomes frozen, (2) foliated ice masses or ice wedges that grow in contraction cracks in the frozen ground, and (3) large clear-ice masses that perhaps represent buried ice or snow.[80]

The active layer, the part of the ground that freezes and thaws seasonally, varies in thickness from a few inches to ten feet and more.[81] Generally this layer, which is most thin in the north, increases in thickness toward the south, just the reverse of permafrost itself. The many factors affecting this depth of thaw are summarized by Black as follows:

> It is at a minimum in peat or highly organic sediments and increases successively in clay, silt and sand to a maximum in gravelly ground or exposed bedrock. It is less at high altitudes than at low altitudes and less in poorly drained ground than in dry, well drained ground. Depth of thaw is at a minimum under certain types of tundra. . . . It is less in areas of heavy snowfall, in regions having cloudy summers, and on north-facing slopes.[82]

The active layer begins to thaw as the snow melts from the surface and increases in depth until about September when refreezing begins.

Permafrost areas are characterized by unique surface forms, most of which result from frost action within the active layer and from the melting of ice-laden permafrost. Water movement in the active layer, accompanied by freezing, may produce a variety of swellings or frost mounds. The largest of these are pingos, which may grow over 200 feet high. They are quite common along the coast of northern Alaska and Canada espe-

Figure 11. Pingo near Tuktuyaktuk, Mackenzie River Delta.

[78] *Permafrost or permanently frozen ground and related engineering problems* (Ann Arbor: J. W. Edwards, Inc., 1947), p. 3. Permafrost as used by Muller is a temperature phenomenon and, thus, may be "dry." Dry permafrost is ". . . usually found in sandy or in other coarse grained clastic material that drains easily." p. 3.

[79] Pewe, *op. cit.*, p. 18.

[80] *Ibid.*, p. 19.

[81] Black, "Permafrost as a natural phenomenon," p. 6.

[82] *Idem.*

Figure 12. Breached crater of pingo.

cially in river deltas (Figure 11 and 12). Other forms such as frost blisters and icing mounds are smaller, composed mainly of ice, and have a life span of only a few years. Besides such non-sorted features, frost action, along with other processes, produces a variety of patterns in permafrost areas. The ice-wedge polygone found near Barrow are examples. Depression forms, such as pits and even lakes, may result from the thawing of permafrost that contains much ice.

Vast areas of the Arctic are characterized by numerous ponds and lakes and boggy soil. Surface drainage is poor and many of the ponds are self-contained most of the time. Such an abundance of surface water could not exist under the precipitation regime characteristic of the Arctic if it was not for the presence of permafrost.

The Cultural Base

The Eskimos

The environment depicted above is that to which the Eskimos adapted. Because of the great success they achieved in this adaptation, they are frequently considered as masters of their environment. Many of their inventions and techniques have yet to be bettered, despite modern materials, machines, and technologies.

The Eskimos, a Paleo-Asiatic people, with a homogeneous, although relatively complex, language, extend in the Americas from the Bering Sea one-third of the way around the world to east Greenland (Figure 13). In latitude their extent is almost as striking, for they range from northwest Greenland, the most northern permanently inhabited place on earth, as far south as southern Labrador, or over 1,700 statute miles. The total area of occupation, however, is much less than the latitudinal and longitudinal limits would suggest. First, most Eskimos are coastal dwellers, although exceptions occur in Alaska and central Canada; second, nearly all of the Eskimos live coastward of the tree line; and third, a very large percentage of the area within their boundaries is uninhabitable, much of it being ice, sea, lake, swamp, and mountains.

The total number of Eskimos in North America is relatively accurately known today because of American, Danish, and Canadian censuses. In 1956 Margaret Lantis wrote that the Eskimos numbered probably 55,000,[83] possibly as many as at any time in history. Of this total, nearly one-half live in Greenland, one-third in Alaska, and one-fifth in Canada. All three political areas have shown substantial gains since World War II with an average rate of increase approaching 20 per cent every ten years. This rate is destined to continue rising as the mortality rate decreases. Such a rate of increase, even though the total population is relatively small for such a vast area, is significant because of the limited food resources in most of the American Arctic.[84]

The Eskimos, although not organized in tribal units like the Indians, usually lived in loosely knit groups within a particular region. Seasonal nomadism, occasioned by hunting conditions, resulted in great variations in the size of the groups from one season to the next as well as variation in the particular site occupied at any one time. Nevertheless, the Eskimos usually associated themselves with a particular region, the name of which often became an integral part of their group name.

[83] "American arctic populations: their survival problems," *Arctic Biology Biology Colloquium*, chap. x, p. 119.

[84] The new settlement at Scoresby Sound resulted from population pressure at Angmagssalik in east Greenland.

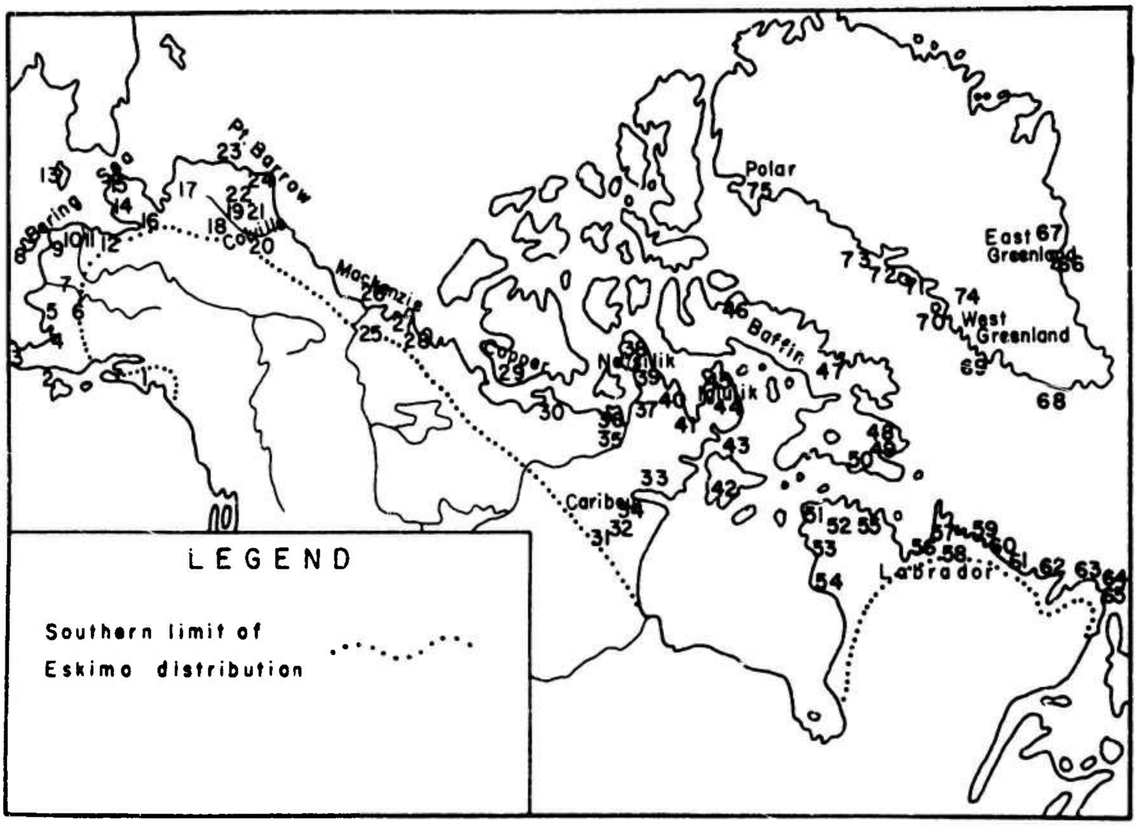


Figure 13. Eskimo distribution. See appendix A for list of the groups numbered. After Weyer, op. cit.; *& Birket-Smith,* The Eskimos.

…ision of the Eskimos into workable units …en attempted by many students who have based their classifications on several criteria. Some validity can be assigned the political basis—that is, Greenlander, Canadian Eskimo, and Alaskan Eskimo—frequently used today, for acculturation has been somewhat varied between each of these groups.

There have been several cultural divisions proposed. One by Steensby [85] is based primarily on the economic relationships of the particular group to the sea and sea ice. His three-fold division is High Arctic, Arctic, and Subarctic with decreasing dependence on or adaptation to sea ice and increasing closer relationship with the open sea. Most Eskimos are included in the Arctic group. The true High Arctic group contains only the Polar Eskimo in northwest Greenland while the Subarctic category includes Eskimos in southern Greenland, southern Alaska, and the Aleutian Islands.

Kroeber, on the other hand, utilized the two-fold division most commonly used, which considers a Western and Central-Eastern grouping.[86] Subdivisions of these two groups have been made in various ways with the most frequently used groupings indicated on Figure 13.

The general homogeneity of the culture of the Eskimos has led to the acceptance of the idea of an "Eskimo Culture." There are many differences, differences that are most evident in those elements which have a close relation to the environment. Kroeber, for example, wrote of ". . . the totality of Eskimo culture as a unit, modified by emphasis or reduction of its traits in direct response to local exigencies."[87] Many of these cultural variations reflect response and/or adaptation to snow and ice conditions.

[85] "An anthropogeographical study of the origin of the Eskimo culture," *Meddelelser om Grønland,* LIII (1905), pp. 39 ff.

[86] *Cultural and natural areas of native North America* (Berkeley, California: University of California Press, 1947), p. 27.

[87] *Ibid.*, p. 22.

Eskimos are hunters and depend almost entirely for their food supply on birds, fish, and land and sea mammals. Although there is much seasonal areal variation in the particular food resource utilized, the Eskimos as a whole depend mainly on the seal. These animals are hunted, depending on the season and locality, from kayaks or on the ice by a variety of techniques, many of which are closely related to sea-ice characteristics. So important is this type of hunting to some groups that they spend the sealing season in villages built on the ice. Not all Eskimos are seal hunters. Exceptions include the Caribou and Colville groups who depend mainly on caribou, the Bering Sea Eskimos who depend upon fish, and the Point Barrow Eskimos who are primarily whale hunters. In every instance snow and ice are important.

Other aspects of Eskimo culture are affected by snow and ice including transportation and shelter. The methods used by the Eskimos to solve these two problems have attracted the attention of early-day explorers and modern-day scientists alike. The dogsled and the snowhouse reflect a degree of adaptation to an environment seldom achieved by man.

The Eskimos of today have all been influenced by civilization to some extent. The degree of cultural change that has occurred varies greatly from one group to another. One of the earliest and most significant changes was the substitution of the rifle for the harpoon. Other changes have included the addition of permanent houses, wooden boats, commercial fishing, store-bought food, and salaried employment. All of these changes have affected the Eskimo's relationship to snow and ice.

The Explorers

The stigma of Greek theory has hampered exploration in the Arctic and the acceptance of the results thereof ever since the first arctic explorer, Pytheas, attempted to penetrate these "lifeless regions." The stigma still prevails in many ways, although in the past few decades scientific research in the Arctic has helped reduce its effect.

The first definite European contact in America was made in the Arctic by the Vikings. These Scandinavian people were explorers only secondarily or by accident for they went to Greenland as settlers. It is believed that they discovered and possibly explored some of the Canadian Arctic; indeed Stefansson maintains that they reached the western part of the Canadian Archipelago.[88]

The first expeditions in the Arctic that have continuity with the present began about the time of Columbus, probably with Cabot in 1498 but possibly with fishermen at even an earlier date. Cabot and these fishermen, like nearly all of the voyagers into arctic waters until the nineteenth century, were summer visitors. Many, however, including such explorers as Hudson, Munck, and James, and unknown numbers of the unheralded whalers, were caught by the ice and forced to spend a winter in the region. Even though they were hardy men and experienced sailors, they were unprepared for such an undertaking and suffered tremendous hardships and great loss of life. Scurvy was the rule and starvation often resulted. Water was frequently a very critical problem, often because of the lack of fuel to melt ice or snow. Those explorers who survived and returned to Europe proclaimed the harsh nature of the environment and emphasized the cold, snow, ice, and darkness. Some of the explorers wrote of the methods they used in coping with these natural hazards. As often as not they were ineffectual or detrimental.

Early in the nineteenth century, beginning with John Ross in 1818, a new period of searching for the Northwest Passage was inaugurated. The explorers of this period had the knowledge of over 200 years of previous, although fitful, exploration to utilize. Navigators knew that in order to go through the passage from east to west they had to be prepared to spend at least one winter in the ice and, as of this period of exploration advanced, many allotted even more time. The ships were strengthened and outfitted for ice and weather, and methods were developed for converting the ships into winter living quarters. They were preferable to structures built onshore.

As more and more winterings were successfully made, techniques became somewhat standardized. A navigator, on deciding he had made as much progress as he could, would pick out a sheltered position that offered the possibility of an early exit in the coming summer. Frequently the wintering position was reached by sawing through the ice. After reaching the desired location, the ship was trimmed, and those items not

[88] *My life with the Eskimo*, p. 200.

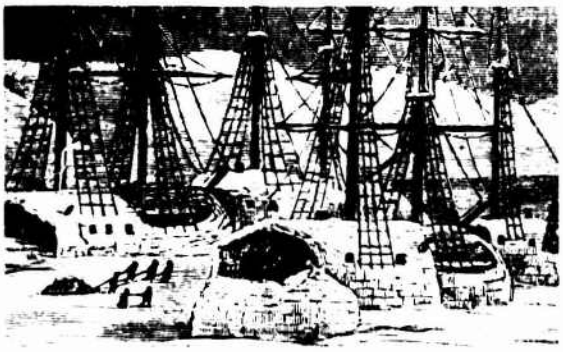


Figure 14. Ships in winter quarters. From Gilder, Schwatka's search;... *(New York: C. Scribner's Sons, 1881), p. 36.*

needed were stored on the ice or on the adjacent land. Usually a stock of food and fuel was also stored in the event of fire on board ship.* The ship was then covered with either canvas or snow blocks, and snow was piled around the sides for insulation (Figure 14).

The use of ships for quarters coupled with the lack of desire of exploration except by sea (certainly, partly because of the lack of a purpose and the lack of knowledge that it could be done) held back the development of new methods of coping with the environment as well as facts about the environment itself. As available food and fuel in the Arctic was considered nonexistent, all was brought on the ships. Only a few explorers were engaged in hunting trips. During the winter there was little need for leaving the ship except for exercise and most frequently that was taken on deck. The clothing, although not good, was adequate as long as the wearer remained on board the ship. The rare times men ventured away from the ship were not without suffering. Clothes, however, changed little in style with the exception of footwear.

Thus, among the explorers, there were relatively few developments that led to a better adaptation to the environment. Although many of the explorers observed various groups of Eskimos and their equipment and techniques, they were reluctant to adopt them. Certainly, one of the reasons for the failure of the Franklin expedition in regions where Eskimos lived was impractical equipment and techniques.

With the loss of the Franklin expedition, the search for the Northwest Passage assumed a secondary role to the search for evidence of the lost explorers. This search continued for a period of thirty years with at least forty expeditions participating. Many of the expeditions used their ships as a base from which to begin sled journeys, a type of arctic travel that until then had been unnecessary and used only sporadically. These sleds were man hauled and carried complete supplies of food, fuel, and shelter (Figure 15). Such simple expedients as snowhouses, seal hunting, seal-blubber lamps, and dogs were generally not even considered for use, which limited operations greatly.

Not all explorations in the Canadian Arctic in the eighteenth and nineteenth centuries were sea oriented. Although one of the charges of the Hudson's Bay Company, which was chartered in 1670, was to engage in the search for the Northwest Passage, it was 100 years before its first attempt was made. In 1770 Hearne traveled to the Arctic Ocean over the tundra and did so by living off the land. He traveled for eighteen months in the company of Indians and adopted their mode of living, unlike the other explorers of the period.

Toward the end of the nineteenth century the desired prize of arctic exploration became the North Pole itself. Although attempts to reach the Pole had been made previously, as by Hudson by ship and Parry by sledge boats, it was not until then that it became the foremost goal. It was realized that ships could not attain the Pole so attempts were made over the ice. As a result there was much experimentation on sleds and

Figure 15. Man-hauled sled with sail. Koldeway, The German arctic expedition *(London: S. Low, Marston, Low and Searle, 1874), p. 430.*

* Fire, often considered the greatest danger in polar regions, was the subject of much precaution. Ice holes were kept open near the ship, fire watches were maintained, and snow blocks were piled up for fire fighting.

methods of living on the ice. Peary utilized such natural possibilities as snowhouses, local game, sled dogs, and, most important to his system, Eskimos. In fact, they were the key to his success.

During the same period, Stefansson began his arctic work and, like Peary, adopted Eskimo materials and techniques. Stefansson went a step farther, however, and became independent of the Eskimos and developed the "living off the land" type of exploration to its highest degree. He extended these techniques out on the sea ice of the Arctic Ocean, a possibility even the Eskimos did not utilize except relatively close to land. A significant difference between the type of exploration engaged in by Peary and Stefansson and that of earlier times lies in the time of year chosen for travel. Snow and ice favor the Stefansson technique but hinder boat movement. Thus, the best season for traveling, from many standpoints, is winter, the season most dreaded by early explorers.

Jeannette Mirsky summed up the gradual improvement in arctic exploration in her statement that ". . . the methods of arctic exploration have become better and better as the explorers have gradually adopted Eskimo ways."[90]

Since Peary reached the North Pole and Amundsen accomplished the Northwest Passage, exploration in the interest of science came to the fore, a trend that has continued on an ever-expanding scale to the present time.

The Settlers

The Vikings became the first Europeans to settle in the American Arctic when they established their farmsteads in Greenland. Ruins show that their barns and dwellings were patterned after Icelandic structures; indeed, their culture as a whole was basically Icelandic. Just what role snow and ice had in their culture can only be inferred, but it must have been an important one. It is also probable that the relationship between the environment and their culture became more intimate as contact was lost with Europe. Whether they adopted many of the ways of the Eskimos, however, is unknown.

The earliest non-Viking European settlements in the American Arctic, except Churchill, Canada, were in Greenland. Early in the eighteenth century, Hans Egede attempted to recolonize Greenland and, although his attempt failed, he remained in Greenland for fifteen years. Missions and trading posts were established quite early and, by the end of the eighteenth century, Greenland had at least ten settlements.

It was not until long after the chartering of the Hudson's Bay Company that the European became more than a summer visitor in the Canadian and Alaskan Arctic. Most of the company's trading posts were established in the Subarctic, although Churchill, founded in the seventeenth century, may be considered on the boundary line between Arctic and Subarctic.

Although settlement in the American Arctic has been proceeding for over two centuries, the number of non-natives in the region is still very low, and, except in Greenland, only a small percentage of the whites are considered permanent residents. Most of the present arctic settlements were actually established after 1920.[91] Most white occupants in the Arctic are connected with some sort of service such as trading companies, missions, government agencies, and the military. Some private enterprise accounts for a few of the white inhabitants; trapping is probably the most important.

Settlements in the American Arctic are very small, in contrast to some of those in the Soviet Arctic. Most frequently they have only a few buildings, generally centered around a trading post. Nearly all of the settlements are located on the coast where ship supply is available and where Eskimos live. The dwellings of the whites in these settlements are usually well insulated wooden structures. Material for house construction is imported, as is most of the food, clothing, and fuel. The attempt has been made to arrange these settlements as much like the "outside" as possible.

Recent Scientific and Military Developments

In the process of conquering the Northwest Passage, reaching the North Pole, and developing an effective method of arctic exploration the major outlines of the Arctic became known. As these developments gradually evolved, the reason for arctic exploration shifted to scientific inquiry. Several techniques have been used in acquiring data. Nansen used a special ship which he allowed

[90] *To the Arctic* (New York: Alfred A. Knopf, 1948), p. 6.

[91] Canada, Department of Mines and Technical Surveys, Geographical Branch, *op. cit.*, p. 55.

to be frozen in the pack ice. Aircraft landings have been made on the Greenland Ice Cap. Submarines have been used under the ice pack. The most systematic and concerted effort has been that conducted in Greenland where data from nearly all disciplines have been gathered.

Although the American Arctic did not have a very important role during World War II, its strategic position was emphasized. This position and the possibility that some of the actual fighting in another war would take place in the Arctic has accounted for the development of warning systems across the American Arctic and of improved techniques for actually operating in the Arctic.

Many of these developments and much of the research being conducted today are concerned with snow, ice, and permafrost and especially as to how they are related to such cultural factors as transportation, construction, and water supply.

Water Supply in the Arctic

The paradoxical nature of the water supply in the Arctic is evidenced in many scientific and popular works dealing with the region. Such statements as: ". . . thirst (that greatest torment of Arctic sledge journeys) . . .[1] and ". . . sufficient water exists in polar regions to sustain life and comfort of human beings at all times . ."[2] are common, despite their apparent contradictory nature. The arctic landscape, characterized by rivers, lakes, and swamps, seemingly abounds in water, water which may be in the solid state. Rivers, lakes, springs, and wells are nearly all frozen during the cold season. Thus, thirst and other types of water shortage are not due so much to the lack of a source of water as to the lack of a technique (and/or the time) for coverting a source into a usable state. Artificially melted snow and ice remain the most common winter supply, whereas naturally melted snow and ice account for most of the summer supply.

Even when an all-year-round source is available in the Arctic, extreme cold greatly complicates above-ground storage and movement, while the cold coupled with permafrost complicates them below the surface. Because of such problems, a recent study concluded that "Water is probably the most important item in the development of any new arctic settlement . . ."[3]

Problems of water movement and storage are not limited to permanent settlements, for travelers have to cope with them as well. The melting of snow and ice or digging through lake ice to the water beneath is time consuming, while keeping water in the liquid state on journeys is difficult, requiring special equipment. In case of emergency, survival may depend upon the ability to maintain a water supply. With increased traffic in polar areas, techniques to insure this supply must be perfected. Historically, most of the winter water problems, non-native as well as native, have been solved on a day-to-day basis. Only in recent years has much attention been given to the possibilities of a continuous supply.

Water Requirements and Uses in the Arctic

The amount of water needed by the human body varies with several individual factors including age, weight, health, and activity.[4] Although no figure is available for the amount absolutely needed under arctic conditions, it is probably on the same order of magnitude as that for the temperate zone, that is, about five and one-half pints per day.[5] The actual amount of water

[1] K. Koldewey, *The German arctic expedition* (London: S. Low, Marston, Low and Searle, 1874), p. 420.

[2] Hostrup, Lyons & Associates, *Study of the mechanical engineering features of polar water supply* (Port Hueneme, California: prepared for U. S. Naval Civil Engineering Research and Evaluation Laboratory, 1953), p. 5.

[3] G. Ridge, *General principles of planning of sub-arctic settlements* (unpubl. Ph.D. dissertation Dept. of Geography, McGill University, (1953), p. 256.

[4] B. Frank, "The story of water as the story of man," *Water* (Washington: U. S. Government Printing Office, 1955), chap. 1, p. 3.

[5] *Idem.*

utilized, however, will normally be much greater than this quantity because water is used for many purposes other than just the satisfaction of thirst. The total volume used will vary with such other factors as standard of living, population density, and availability.

It is a common belief that water consumption in the Arctic is not so great as in temperate or tropical regions. Many observations made by arctic writers tend to indicate that this belief may be erroneous. The Eskimos are reported as being heavy water drinkers.[6] Although actual quantities consumed have apparently never been systematically measured, there are some recorded observations which give indications of their possible magnitudes. John Murdoch noted that at the summer camps of the Point Barrow Eskimos there was

> . . . always a bucket of fresh water in the middle of the circle, with a dipper to drink from. Hardly a native ever passed the station without stopping for a drink of water, often drinking a quart of cold water at a time.[7]

Stefansson once wrote that one of his Eskimo guides in the Mackenzie Delta area liked ". . . to drink six cups of tea 'everytime' and that means about five times a day. A good deal of water is drunk too."[8]

The above observations indicate that not only is a great total quantity consumed during a day but that a large volume is consumed at each drinking. Crantz offered an explanation of the latter condition when he wrote that because the Greenland Eskimos ". . . never drink but when they are dry, they pour in so much the more all at once."[9] Birket-Smith, who writes that the Eskimos' only display of a lack of moderation is in their water drinking, believes that the great quantity they consume ". . . is probably connected with their specialized meat diet."[10] Stefansson, however, has suggested that it is their means of compensating for the ". . . streams of perspiration running down their bodies . . ." while in their homes[11] Great consumption by the Eskimos does not seem to be limited to their homes. On hunting trips they have been known to stop because of thirst ". . . three or four times in an afternoon and dig a hole in the ice with their knives to get water . . ."[12]

Although it is generally the Eskimos who are credited with being "thirsty souls," apparently a desire for great quantities of water under arctic conditions is not limited to them. Some subjective statements have been found in the literature which seem to indicate a great increase in desire for water with time spent in the Arctic. One party mentioned that "Gradually however we found ourselves falling victims to the water habit and now we drink as much as the Eskimos."[13]

Many of the statements about great quantities consumed show that the desire (or need) is increased greatly as a result of sledge trips where water consumption has been at a minimum. Koldewey wrote that, after a five-week sledging expedition,

> Our exceptional circumstances caused the cook to wink at the consumption of his melted snow-water, to which we applied ourselves unmolested: to satisfy ourselves was really hard work.[14]

Such a statement probably indicates dehydration that has resulted from insufficient water intake while engaged in the difficult task of sledging.

Tests near Churchill, Manitoba, showed

> . . . that inability to insure a constant, adequate supply of fluids was a serious problem in freezing weather even when snow and ice are abundant . . . . when troops had to collect snow and

[6] See, for example, J. Bilby, *Among unknown Eskimos* (London: J. B. Lippincott Co., 1923), p. 98 and D. T. Hanbury, *Sport and travel in the northland of Canada* (New York: Macmillan Co., 1904), p. 135.

[7] *Ethnological results of the Point Barrow expedition* (Washington: U. S. Bureau of American Ethnology. Ninth annual report, 1887-88, pub. 1892), p. 64. Much emphasis is placed on the fact that very cold water is preferred by most Eskimos. However, Turner offers an exception in his *Ethnology of the Ungava District, Hudson Bay Territory* (Washington: U. S. Bureau of American Ethnology. Eleventh annual report, 1889-90, pub. 1894). He writes that if the ". . . weather be very cold they often drink the water which has been heated on a fire, asserting that the hot water does not weaken them as much as cold water would do." p. 213.

[8] *The Stefansson-Anderson arctic expedition* (New York: American Museum of Natural History. Anthropological Papers, 1919), XIV, p. 157.

[9] *The history of Greenland* (London: J. Dodsley, 1767), I, p. 236.

[10] *The Eskimos* (New York: E. P. Dutton and Co., 1935), p. 51. He also writes that ". . . the constant swilling undoubtedly saves them from a lot of rheumatism in their old age." p. 51. Rasmussen in "Intellectual culture of the Caribou Eskimos," *Report of the fifth Thule expedition, 1921-24*, VII, No. 2 (1930) agrees with Birket-Smith that an exclusive meat diet explains the great water consumption observed. p. 45.

[11] "The North American Arctic," *Compass of the World* (New York: Macmillan Co., 1945), p. 70. The Eskimos, except for some groups such as the Caribou Eskimos, possess (or, at least, formerly possessed) basically a "tropical environment" within their igloos, even in the middle of the cold season. However, the Caribou Eskimos, who go through the winter season without auxiliary heat, are also big water drinkers.

[12] Hostrup, Lyon, & Associates, *op. cit.*, p. 18, as quoted from an unacknowledged source.

[13] *Idem.*

[14] *Op. cit.*, p. 446. D. Jenness in *People of the twilight* (New York: Macmillan Co., 1928), recorded a similar experience. "One man drank two large cups of soup, two of tea, and nine of ice-cold water, all within the space of three hours. At times I myself almost rivalled his feat without either quenching my thirst or feeling that it was in anyway abnormal." p. 102.

> ice individually, chronic thirst was a common complaint. In fact, one cause of dehydration exhaustion was seen.[15]

The problem of thirst goes beyond the individual. As Payer noted, it is ". . . remarkable how rapidly the demoralization produced by thirst extends, when any one of the party begins to show signs of suffering from it."[16]

The second most important use of water in the Arctic is in cooking. At times, it is difficult to separate cooking from the preparation of water for drinking, for quite frequently the two processes are carried on simultaneously.[17] The broth that results is consumed as a beverage. The natives and a few explorers often ate their food without cooking it, especially during the winter. Consumption of uncooked food was often by preference, although lack of fuel must be considered a contributing factor. Under many situations fuel could be spared only for melting ice or snow. However, Driver and Massey state that,

> Since it often took hours to melt ice and boil food in the subzero temperatures, the hungry Eskimos frequently ate their meat raw rather than wait for it to be boiled.[18]

Although more water is used in the Arctic today for cooking than in pre-contact days, boiling is not the exclusive cooking method that it was formerly.

Water for purposes other than cooking and drinking was used in small quantities by both the Eskimos and the early explorers. Washing among the Eskimos was, from all reports, extremely rare. Their method of cleansing used water indirectly, through wiping perspiration from their skins as it formed on them in their hot igloos. The explorers went into the Arctic with the idea of limiting the amount of washing and in some instances of ignoring it completely. This attitude prevailed especially during sledging journeys.[19]

Diamond Jenness, in 1918, considered that ". . . the one virtue which the Eskimo of northern Alaska lacks is cleanliness but even in this he has made a great stride forward, . . ."[20] The Eskimos, in satisfying this new need, have had to do so within the limits of their capabilities of increasing the quantity of water. Often, instead of increasing the actual quantity used, they increased the effective quantity by re-using the same water several times. Possibly one of the best descriptions of the form such a conservative approach can take is not from the Eskimo literature but rather from that of the Samoyed. Water, which the Samoyed women obtain by melting snow, is used for washing prior to each meal. They

> . . . take a large mouthful of water, gargle it in the throat, then spit it into their hands and apply it to the face. With one mouthful of water they thus in turn rinse their teeth, hands and face and always in the [sic] sequence.[21]

People dwelling in the Arctic today demand much more water for washing than the aborigines or the early explorers ever did. Despite the demand, conservative measures are still maintained. Such signs as "One Shower Per Week" and "No Showers For Transients" were fairly common along the DEW Line in the spring of 1957.

It is not generally realized that the Eskimos used water for purposes other than drinking and cooking. These uses, when they occurred, normally did not require great quantities of water.

Such additional needs of water might be illustrated by two examples from the Eskimo culture. One need was, and still is, quite practical in that it eased the transportation problem. As cold snow exerts a great drag on sled runners, any method which will reduce this drag will increase sledging efficiency. The most effective technique is to apply periodically a thin stream of water to the bottom of the sled runner which, when smoothed and

---

[15] R. E. Johnson and R. M. Kark, *Feeding problems in man as related to environment* (Chicago: U. S. Army Medical Nutrition Laboratory, 1946), p. 26.

[16] *New lands within the Arctic Circle* (New York: D. Appleton and Co., 1877), p. 253. He continued that "Habit, however, enables men to struggle against thirst more successfuly than against hunger," p. 253.

[17] Cooking in the Arctic under primitive conditions was almost invariably direct-fire boiling and therefore dependent on water.

[18] "Compartive studies of North American Indians," *Transactions of the American Philosophical Society*, New Series, XLVII, Pt. II (1957), p. 229.

[19] For example, W. Pike in *The Barren Ground of northern Canada* (New York: Macmillan Co., 1892), states: "There was no attempt at washing made by any of the party during the whole time that we were out, and indeed it would have been an impossibility, as our small fires were only just sufficient to melt the snow for cooking purposes," p. 96.

[20] "The Eskimo of northern Alaska: a study in the effect of civilization," *Geographical Review*, V (1918), p. 99. This "conversion" to cleanliness was not made with unmixed blessing, for, as John Teal has stated in "Patterns of discrimination in the Arctic," *Encyclopedia Arctica*, VIII (unpubl.), there have been demands ". . . that every person bathe hands and face before each meal . . . [despite the fact that] the reuse of the same water and towel spreads contagious diseases . . ." p. 3. Stefansson in "Northern Alaska in winter," *Bulletin, American Geographical Society*, XLI, No. 10 (1909), notes "That the washing, which takes place frequently, and on all possible pretexts, is less for hygienic or aesthetic purposes than for ceremonial ones as shown pretty conclusively by the fact that an entire household often washes in one basinful of water . . ." p. 608. Stefansson also observed ". . . twenty six people wash in about a pint of water, . . ." *Idem.*

[21] K. Donner, *Among the Samoyed in Siberia* (New Haven: Human Relations Area Files, 1954), p. 119.

frozen, reduced the friction between the runner and the snow.[22]

Another use of water considered necessary by the Eskimos in order to insure an adequate and continuous supply of food is reported by Stefansson as follows:

> It is said that no animals (sea mammals) would allow themselves to be caught by man were it not for their thirst; they had no fresh water to drink where they lived in the sea. For this reason a seal was given water when brought into the house. Beluga and balaena were given water on being brought to shore. . . . The soul of a seal thus treated will be grateful and when it has again become a seal it will allow itself to be caught by the same man, partly through gratitude, partly because it knows that at his house it is sure of a drink of fresh water. The water may be of any source, at Nuvurak it was generally either snow water or water made of an old sea ice cake.[23]

In recent years a new type of person has been entering the Arctic—a type whose culture is not adjusted to small amounts of water, as is the case of the Eskimos, and whose attitudes are not adjusted to it, as in the case of the explorers. These people, with their needs of water for dishwashing (unthought of among the Eskimos and generally not practised by the explorers), laundering, bathing, water toilets, photo-processing, steam production, and the like, demand proportionately more water than their predecessors. This conclusion is valid for civilian and military personnel alike.

Because of these new demands, per capita consumption is becoming greater. New supplies of water have to be found or else new techniques have to be developed for the mass processing of snow and ice. Information about actual demand under arctic conditions would facilitate development and processing, but such information is not yet available. Studies made thus far are not satisfactory. Most consumption in the Arctic has been on an individual or family basis, for which records are unavailable. The value of such records would be limited, for consumption under such conditions would probably differ greatly from what it would be if public facilities were available.

As most of the studies made to date have been carried out under the auspices of the military, the values arrived at probably differ some from those used in civilian establishments. Tables of recommended-per-capita use are based on many factors, including: (1) the seasonal source of water, (2) the permanency of the site, and (3) the size of the establishment. The values vary from one gallon per person, under combat conditions as an absolute minimum for drinking and cooking,[24] to 100 gallons per person for a permanent large group with water obtained from an unlimited source.[25]

[22] See T. Mathiassen, "Material culture of the Iglulik Eskimos," *Report of the fifth Thule expedition, 1921-24*, VII, No. 1 (1928), for a detailed description of this technique.

[23] *The Stefansson-Anderson arctic expedition*, p. 351. Rasmussen has written that, Iglulik, "When a seal is brought into a snow hut, a lump of snow is dipped into the water bucket, and allowed to drip into the seal's mouth; it is the soul of the seal that drinks. In summer, it does not require water." "Intellectual culture of the Iglulik Eskimos," *Report of the fifth Thule expedition, 1921-24*, VII, No. 1 (1929), p. 184.

[24] H. Eisberg and J. Owens, *Fundamentals of arctic and cold weather medicine and dentistry* (Washington: Bureau of Medicine and Surgery, U. S. Navy Department, 1949), p. 73. See Appendix II for recommendatinn chart.

[25] Hostrup, Lyons & Associates, *op. cit.*, p. 23.

Sources of Water in the Arctic

In one form or another ". . . sufficient water exists in polar regions to sustain life and comfort of human beings at all times."[26] Sources of water generally are more varied in the Arctic than in other regions because snow and ice are available much of the year. This seasonal variety is not always beneficial, for it often necessitates the use of different sources at different times during the year.

The assumptions which have served as guides in the following discussion include: (1) a water source may become a source only when it is recognized and accepted as such,[27] (2) a source may become a source only when adequate techniques for its development and utilization are available, (3) a source has to have the necessary quality for the purpose needed,[28] and (4) winter

[26] *Ibid.*, p. 5.

[27] Snow, to some of the early explorers, was not a source of water because of their prejudices against it.

[28] Salt water, for example, although used in cooking is too saline for drinking. Sea ice when melted may serve both purposes.

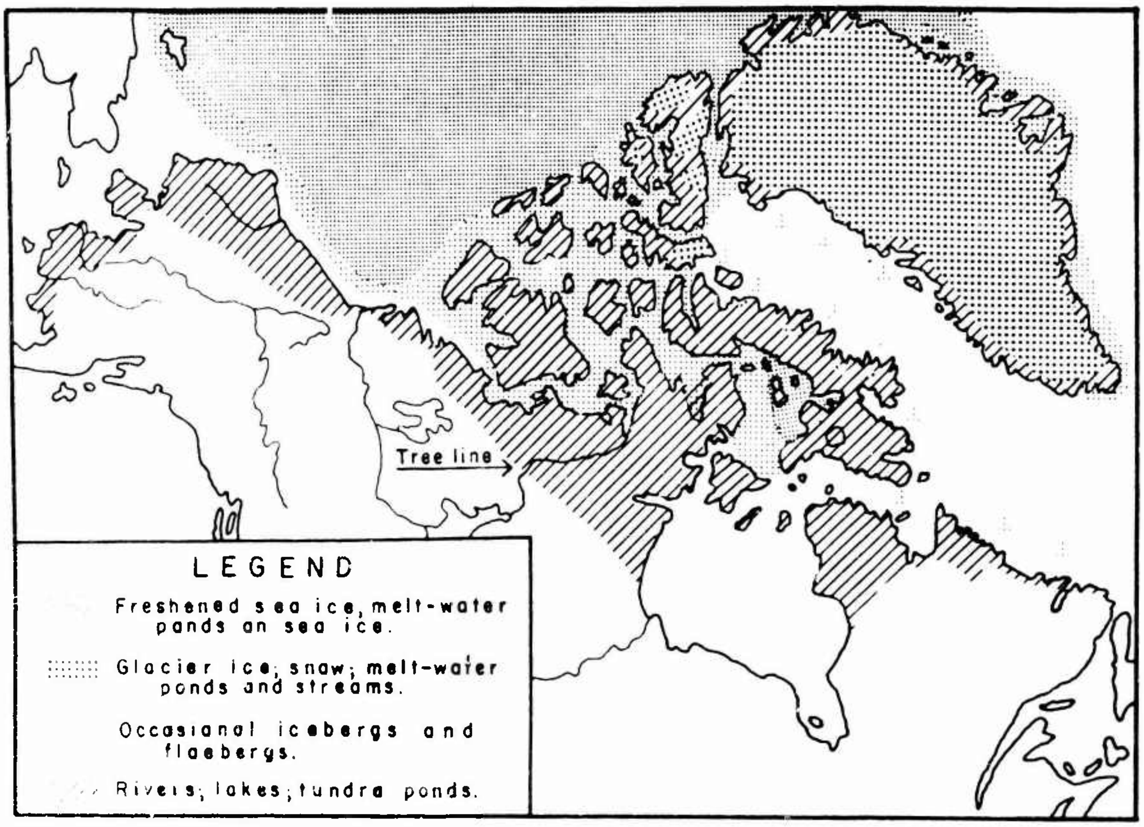


Figure 16. Sources of fresh water during the warm season.

is the most difficult season from the standpoint of water supply in most of the Arctic.

Summer Sources

During the warm months of the year in the Arctic [illegible] good water is found almost everywhere [illegible]. Fresh water is available from rivers, lakes, and pools (Figure 16), most of which depend upon the melting of snow and ice. However, those rivers and streams, dependent upon snow melt, may dry up after the thaw season [illegible]. Glacial streams are sources of abundant water in the summer. However, they usually contain a large concentration of suspended sediments and are therefore of low quality. Water accumulated in ponds in the tundra usually does not dry up but it quite often has a brownish color and, although drinkable, is often considered unappetizing. With such a wide distribution of available water sources, summer camp location is not particularly difficult. The most frequent locales for limited potable water supply in summer are the brackish-water coastal areas. Jeffers gives a specific example along with a solution when he writes that

> To get fresh water on the sand islands is more difficult in summer than in winter because of the prevalence of shoal areas behind the barriers and the long hauls involved. The ponds on the barrier islands are salty. At one island station this past season [1950] an ice house was built and insulated with quonset-hut material with very good results[31]

Another location where summer sources are at a minimum is in the mountainous parts of the Arctic. There the frequency of ponds is not so great as on the plains, rivers, on the other hand, are quite frequent so that one is generally never far from a water source.

Available water is not limited to land areas.

> In summer you are always sure of perfectly fresh water at sea by dipping it up from the hollows

[illegible] *The* [illegible] p. 7[illegible]

[illegible] Hastings, Lyons & Associates, op. cit., p. 32. Hanbury, op. cit., p. 134.

[31] "Triangulation parties conquer Arctic to map Alaska," *Civil Engineering* XXI, no. 2 (1951), p. 35.

> in old ice. . . . Even on this year's ice, which itself is salty, you find in midsummer water plenty fresh enough for drinking . . .[32]

This water is not only of good quality but of adequate quantity. Amundsen, as a result of his experience during the drift of the *Fram*, writes:

> One great advantage in drift ice is that it affords an abundant supply of water. On almost every floe there is a pool of the most beautiful drinking water and we even allowed ourselves the luxury of washing and bathing in fresh water.[33]

Zubov reminds us that, despite the good quality and great quantity available in these ponds, they are ". . . not restricted to the southern regions of the Arctic Ocean, where such ponds have long served as a source of fresh water for seamen."[34] The Russians on the scientific drifting station in 1950–51 obtained their fresh water in summer from the numerous ponds.[35]

The water in these ponds generally comes from the melting of the sea ice, although it may also come from melting snow and even from the accumulation of rain.[36] No matter what the origin, water found on sea ice is ". . . usually fresh enough for cooking . . . A distance of 30 to 50 feet from the edge of the floe should be adequate to prevent contamination from sea water."[37]

In summer fresh water is found on the surface of salt-water leads where it accumulates as runoff from the melting of freshened (old) sea ice.[38] As fresh water is less dense than salt water, it tends to remain at the surface. According to Stefansson, this fresh water may be as much as fifteen feet deep and of such a quality that ". . . you can drink directly out of the sea."[39] One of the first reports of such water usage was made by Baffin when he wrote: ". . . wee have seene them drinke the salt-water at our shippes side; but whether it be usuall or no, I cannot tell."[40]

Even on the Greenland Ice Cap, water can be obtained easily in summer from streams and lakes.

> Streams in the upper ablation zone are closely spaced, and their volume of flow is more than adequate during the warm period. Lakes are less desirable sources of water because their shores are slushy in summer.[41]

Summer sources are not limited to liquid water, for today ice is frequently cut and stored for summer melting. Grounded icebergs also furnish an abundant source in some localities; and, even in summer, snow and ice may serve as the basic sources of water on the Greenland Ice Cap.

Winter Sources

The cold season is the important season in regard to water sources, as well as to the processing of these sources. Few are the areas in the Arctic where a summer source is more difficult to find and process than a winter source. As discussed above, this situation may occur along brackish-water coasts, but it also prevails in certain tundra areas where the best lakes may not be available during the summer because transportation to them is hindered by the boggy terrain. While winter supply requires greater labor in preparation, it often requires less treatment after it is obtained. Snow and ice usually provide water of greater purity than can be found in the tundra ponds of the warm season.

Winter sources, although most commonly in a solid state, may also, under certain conditions, be in a liquid state. During winter, water, unless transported rapidly or kept warm during transport, will freeze and have to be treated as a solid source.

Snow. Snow as a source of water was used by the Eskimos and some of the explorers only when some other form was not available.[42] Snow is used occasionally today. Although not so desirable a source as ice, it nevertheless forms a quite reliable source in most of the Arctic during much of the year. There are relatively few areas in the Arctic where snow is not available during most

---

32 Stefansson, *Arctic manual* (New York: Macmillan Co., 1944), p. 240.
33 Hostrup, Lyons & Associates, *op. cit.*, quoted on p. 8.
34 *Op. cit.*, p. 35.
35 Somov, *op. cit.*, I, sec. 1, 6.
36 Rainfall, as shown by A. Alter, *op. cit.*, generally will be only sufficient to supplement other sources. Nevertheless, at times it may prove important. p. 219. Koldewey, *op. cit.*, states that ". . . water for cooking and drinking we find plentifully on the floe after the rain, and this is acceptable, as our brandy would soon come to an end if we had to melt the snow." p. 159.
37 Eisberg and Owens, *op. cit.*, p. 73.
38 The fresh water on the lead freezes and the ice from it is fresh as soon as frozen. Ordinary sea ice has to age, however, before it freshens. Even after the freeze-up, the water beneath a lead may still be fresh and can be obtained by chiseling a hole through the ice. This freshness disappears with time as the salt water beneath mixes with the fresh water above. See Stefansson, *Arctic manual*, p. 240.
39 *The friendly Arctic* (New York: Macmillan Co., 1921), p. 547.

40 C. R. Markham, "The voyages of William Baffin, 1612-1622," *Hakluyt Society*, LXIII (1881), p. 37. See also, A. H. Markham, "The voyages and works of John Davis," *Hakluyt Society*, LIX (1880), p. 20.
41 G. Holmes, "Topographic and hydrologic studies," *Project Mint Julep*, Pt. I (1955), p. 16.
42 The RCMP today follows the same practice. H. W. Stallworthy in "Winter patrols in the Arctic," *Royal Canadian Mounted Police Quarterly*, II (1934), states that "Experienced northern men never use snow water to make their tea if ice is available." p. 20.

of the long winter. This general availability occurs despite the fact that much bare ground and bare ice (both sea ice and lake ice) are present as a result of wind sweeping. Wind-swept areas are generally not large enough to preclude the availability of snow within relatively short distances from most locations where it has been piled into drifts[43] (Figure 17). Wind sweeping may be more beneficial than detrimental as evidenced by Greely in his field note of January 17, 1882. He wrote that, at Fort Conger,

> Though there has been during the winter a moderate amount of snow, considering the low temperature, yet the hill tops are now quite bare and show less covering than in October. Yesterday's storm has stripped every exposed place of its usual snow, to pack it in dense hard drifts in the hollows of the ground and the cracks and other interstices of the harbor-ice. For the first time during our experiences, it would now be possible to cut blocks of snow and build a snow-house.[44]

Of course, for most of the Arctic snow will not be available until toward the end of summer when it begins to remain on the surface. This condition is as true for sea ice, after the sea ice has formed, as it is for the land surface. Rasmussen, in taking a short cut across the new ice of Queen Maud Gulf in November, 1923, noted that

> . . . every afternoon we had to drive a considerable distance in towards the old ice and pick a place to bivouac. And, as a matter of fact, this was necessary in order to renew our supplies of drinking water.[45]

In the Arctic a generally adequate cover of snow for water supply occurs despite the fact that a relatively small amount of snow actually falls. Nearly all of the snow that does fall remains throughout the entire cold period, although it may be moved about until it is wind packed.

There is a great difference in the amount of water available from different types of snow; all snow, then, is not of the same value as a water source. New snow does not have so great a water content ~~per volume~~ as does granular snow and, thus, takes more energy to convert into a usable state. The best snow, according to Stefansson, is ". . . so granular that it will not even cut into blocks. You bring this snow to the house in buckets or wrapped in a piece of cloth or skin."[46]

The volume of water produced from a given volume of snow varies greatly depending on the density of the snow. Statements such as, "Seventeen cubic inches of uncompacted snow, when melted, gives only 1 cubic inch of water"[47] are common, and serve to indicate that the size of the unit demanding water is important in determining the feasibility of the use of snow as a water source.

The quality of snow also affects its value as a source. Many reports state that the taste of food cooked in snow water is quite flat, a condition that can be explained by the fact that snow is relatively pure, and therefore when melted, theoretically at least, contains no salts. Boyd found the chloride concentration of snow near Point Barrow to be less than ten ppm.[48] Birket-Smith notes that, "If snow is old and granulated, the water is just as good as that from ice, whereas fine, soft and porous snow gives a flat taste. . ."[49]

Quality of snow is affected easily by external factors. Captain Bernier, who spent a winter at Parry's "Winter Habor," reported that until November 15 his crew

> . . . used ice from which to obtain [their] supply of water, but [then] found snow at a more convenient distance. The snow did not furnish water as free from foreign materials as the ice. The wind had caused sand and other detritus to mix with the snow throughout, while with ice the sand settled to the bottom.[50]

Contamination by sea water (in the case of snow on sea ice), animal wastes, soot from stoves, and the like, has to be considered. Population density and cultural practices are significant in regard to snow contamination.

Snow Eating. Although snow is generally available during arctic winters, it has not always been

---

[43] P. Siple, in his *Adaptations of the explorer to the climate of Antartica* (unpubl. Ph.D. dissertation, Dept. of Geography, Clark University, 1939), discusses the water supply of Antarctica. At one point he states that "The problem of snow for a water supply in a large area of rock exposures becomes difficult and requires much labor in securing it, a particular disadvantage in bad weather." p. 230. The same condition prevails under similar circumstances in the Arctic.

[44] *Three years of arctic service* (New York: C. Scribner's Sons, 1894), p. 139.

[45] "Intellectual culture of the Copper Eskimos," *Report of the fifth Thule expedition*, 1921-24, IX (1932), p. 3. Another reason for sledging in to the old ice was to keep from being caught unawares in the case of ice breakup at night.

[46] *Arctic manual*, p. 242.

[47] Dept. of the Army, *Administration in the Arctic*, Field Manual 31-72 (1951), p. 38.

[48] W. Boyd and J. Boyd, "Water supply problems at Point Bartow," *Journal American Water Works Association*, LI, No. 7 (1959), p. 892.

[49] "The Caribou Eskimos, material and social life and their cultural position. 1. Descriptive part," Report of the fifth Thule expedition, 1920-24, V (1929), p. 134.

[50] Canada, Dept. of Marine and Fisheries, *Report on the Dominion Government expedition to the northern waters and Arctic Archipelago* . . . (Ottawa, 1910), p. 95.

used, even in times of extreme thirst. The use of snow in quenching thirst, both in the solid form and after it has been melted, has had a curious history. At times it has been considered as poisonous while at others merely to be avoided.[51] The current trend is to use it, but with caution. Negative – does make [illegible] than it gains

There are contrasting statements regarding the Eskimos' attitude toward snow eating. John Ross, in the journal of his second voyage, writes that ". . . the natives prefer enduring the utmost extremity of this feeling [thirst], rather than attempt to remove it by the eating of snow."[52] Payer, after confirming Ross' observation regarding the Eskimos, goes on to state that ". . . it is only the Tschuktschees who indulge in it as a relish with their food. . . ."[53]

Other accounts, however, indicate that the Eskimos did eat snow. One of Rasmussen's informants told him that

> . when the Netsilingmiut do not catch any seal and can get no blubber, they have to quench their thirst by eating snow. They cannot get water, because they live far out on the salt ice in winter.[54]

Hooper, after mentioning the "constant thirst" of the Eskimos, adds that "when traveling, if the weather is not too cold, they are constantly taking up handfuls of snow to eat. . . . The Innuits appear to suffer no ill effect from it."[55] Hooper, in qualifying his statement, introduces the fact that the degree of cold apparently was a determining factor on whether snow was eaten or not. Stefansson affirms that the Eskimos used to eat snow as needed, providing no other source was available, and that this was done no matter what the temperature because the natives knew the techniques of eating cold snow. The aversion the natives of North America have toward eating snow resulted from contact with whites and has been inculcated to the extent that they now mistake ". . . it for a taboo, like not working on Sunday. . ."[56]

Although the Eskimos' attitude toward snow eating is not clear from the records, it is clear what many of the explorers thought about such a practice.

Payer probably has contributed the best description of the effects improper eating of snow can cause as well as the attitudes prevalent regarding snow eaters during the latter part of the nineteenth century.

> Many try to relieve it [thirst] by using snow; which is especially pernicious when its temperature falls considerably below the point of liquefaction. Inflammation of the mouth and tongue, rheumatic pains in the teeth, diarrhea, and other mischiefs, are the consequences, whenever a party incautiously yields to the temptation of such momentary relief. It is in fact a mere delusion, because it is impossible to eat as much snow—say a cubic foot—as would be requisite to furnish an adequate amount of water. Snow of a temperature of 37° to 50° (C.) below zero feels in the mouth like hot iron, and does not quench, but increases thirst, by its inflammatory action on the mucous membranes of the parts it affects. . . . Snow-eaters during the march were regarded by us as weaklings, much in the same way as opium-eaters are.[57]

Despite such fear of eating snow, there were many instances when even the most cautious explorer resorted to it. Kane observed that his party ". . . could not abstain any longer from eating snow: our mouths swelled, and some of us became speechless."[58]

Despite the general aversion to eating snow in the middle of the nineteenth century, by the end of that period some explorers were accepting the practice even if not actually advocating it.[59] In 1896 Caspar Whitney wrote that

[51] Hippocrates for example in writing about water stated "Those from snow and ice are [illegible] bad, for when once congealed they never recover their former nature, for whatever is clear, light and sweet in them is separated and disappears, but the most turbid and weightiest part is left behind." This statement appears in his "On airs, waters and places" in R. Hutchins' Great books of the Western World. 10: Hippocrates, Galen (Chicago: Encyclopedia Britannica, Inc., 1952), p. 12.

[52] Narrative of a second voyage in search of a north-west passage (London: A. W. Webster, 1835), I, 248.

[53] Op. cit., p. 254.

[54] The Netsilik Eskimos [illegible] Report of the Fifth Thule expedition 1921-24, VIII [illegible] 487. See also [illegible] [illegible] where he writes that [illegible] p. 135.

[55] [illegible] Office, 1884 [illegible]

[56] Stefansson, Instructor's manual for the Arctic (typed copy at the Arctic, Desert, Tropic Information Center, Research Studies Institute, Maxwell Air Force Base), p. 77. H. Ingstad, in Nunamiut (London: Ruskin House, 1954), states that among the Nunamiut of inland Alaska there is a rule ". . . that snow must never be eaten, because it is weakening." p. 240.

[57] Op. cit., p. 253.

[58] Arctic exploration: the second Grinnell expedition in search of Sir John Franklin, 1853, '54, '55 (Philadelphia: Childs and Peterson, 1856), I, 197.

[59] Despite current information, there are still articles written in the vein of those of the mid 1850's. Two articles and a book by Marguerite G. Tate emphasize such attitudes. Mrs. Tate states, in "Marooned in the clouds," The Atlantic Monthly, CLXXXI, No. 2 (1948), that "Enemy number two soon began to manifest itself. Thirst. Harvey and Sue had warned us that to eat snow was tantamount to inviting slow death into our midst. Lung frost is a terrible malady, and is almost a sure result if snow is eaten at high altitudes in a thirty below temperature." p. 58.

Snow eating featured in many survival experiences which occurred during World War II. Some of these experiences in the Arctic

> There is a difference in eating snow and sucking the moisture from it; neither is satisfactory but the former is harmful to the traveller and pretty certain to be followed by increased thirst and cramps.[60]

Following Whitney, Stefansson wrote in many of his publications that the eating of snow is not only safe but practical.[61] He has described a technique that adds the eating of cold snow to the list of ways of quenching thirst. One should

> . . . begin eating snow on any day at the first sign of thirst. . . . If you do this, and eat only a little at a time, taking the snow in the palm of your mitten and licking it as if you were licking granulated sugar, then you will not feel the slightest bad effects. . . . But if you are properly dressed there is a better way: you will then be so warm, no matter how cold the weather, that you can afford to take off your mitten, pick up a small handful of snow and squeeze it for a minute or two, rolling it around in your hand until it gets slushy, like sherbert, whereupon you can take more of it at a time than if you lick dry snow and will have more of the feeling that you are taking a drink.[62]

A recent manual prepared by the Western Electric Corporation for use along the DEW Line incorporates Stefansson's suggestions, but adds further cautions, as follows:

> Do not swallow snow in lumps — let it melt slowly in your mouth. If you are cold, or hot or tired, go easy on eating snow. It will lower your body temperature and make you more thirsty.
>
> If you try to eat snow at −30° F., without first warming it with your breath or hands, you will freeze your mouth.[63]

Melted Snow. Melted snow or "snow water" has variously been considered as detrimental, disagreeable, tolerable, and beneficial. Snow water is used by all Eskimo groups at times, although some groups have taboos restricting its use. It may also be the only water used under certain conditions, even though other water is available. Eskimo women of the Mackenzie Delta ". . . at times of childbirth drank only snow water. . ."[64] while Iglulik women who lose their children ". . . must never drink water from melted ice, but only water from melted snow."[65]

Explorers often looked on snow water with disfavor for one reason or another. James, reporting his wintering experiences in Hudson Bay, states: "Melted snow-water is very unwholesome, either to drink or dress victualls. It made us so short-breathed that we were scarce able to speak."[66] Munk, wintering during the same period, mentions that when

> . . . frost got the upper hand, the beer froze to the bottom, so that I was afraid of letting the men drink of it before they had well melted and boiled it again; for which reason, I had every fresh barrell, as it was taken up for consumption, boiled fresh, because, in any case, it was better than snow water, which otherwise would have to be melted for drinking or mixing with wine.[67]

About 200 years later Payer carried into the Arctic the general notion, prevalent in Europe at the time, that the presence of goiter in the Alps was caused by the use of snow water. While in the Arctic, Payer and his men used only snow water for their drink and, as none of them contracted goiter, he concluded that they ". . . were a living refutation of the opinion shared by many that its constant use generates this disease in the inhabitants of the Alps."[68]

Most of the objections to snow water stemmed from the difficulties involved in its preparation. There were some however, who, despite these difficulties, drank it enthusiastically at times. M'Dougall once wrote:

> We were therefore compelled to melt a little snow, and I doubt if any *bon-vivant* ever appreciated the most costly wine, with greater *gout* than we did the scarcely dissolved snow.[69]

Ice. Ice became the first recorded "drink" of the Eskimos when Frobisher wrote that ". . . for

have been summarized by Howard as follows: [illegible] ate snow reported [illegible] Many reported [illegible] thirst [illegible] 1958, p. 16.

[illegible] New York: Harper and Bros., 1946, p. 266.

[illegible] p. 14[illegible]

[illegible]

[illegible] p. [illegible]

Stefansson, *The Stefansson-Anderson arctic expedition*, p. 133.

Rasmussen, "Intellectual culture of the Iglulik Eskimos," No. [illegible], p. 1[illegible]. The Iglulik Eskimos have a rule that "People living in a snow hut [illegible] built on the ice must not use last year's ice for [illegible] water, but only snow; if the fresh ice which was once sea [illegible] be used for drinking water, then the [illegible] ice will break up and the [illegible] be carried out to sea." [illegible] p. 19[illegible]

[illegible] The voyage of Captain Luke Foxe of Hall, and Captain [illegible] of Bristol, in search of a north-west passage in 1631-32. [illegible] LXXXIX, 1894, p. 528.

[illegible] The expedition of Captain Jens Munk to Hudson's Bay [illegible] north-west passage in 1619-20," *Hakluyt Society*, XCVII [illegible]

[illegible]

The eventful [illegible] H. M. Discovery Ship "*Resolute*" to the Arctic [illegible] London: Brown, Green, Longman [illegible] p. [illegible] common drink they eat ice to quench their thirst."[70] This use of ice falls basically in the same category as the eating of snow, although, from various reports, it seems to be somewhat preferred to snow. M'Dougall indicated such preference in his writings. For example, he wrote:

> I detected one of the sledge's crew eating snow; but having had practical experience of the injurious effects of such a remedy, I insisted on his discontinuing it. When close to the ravine, we fortunately discovered some fresh-water ice, which tended, though not wholly so, to satisfy our wants.[71]

Ice, like snow, is most commonly used in the melted state. If both snow and ice are present, ice is usually preferred. It is a better source of water than snow because its greater density assures a greater quantity of water for a given volume of solid. It may also be used as a summer source when cut and stored. There are many types of ice available as water sources to the arctic dweller or traveler.

Fresh-water Ice. As a large proportion of the land area is covered by lakes and rivers which freeze during the cold season, fresh-water ice is plentiful throughout nearly all of the Arctic. It is less common in mountainous and hilly sections than on the low-lying plains.[72]

Glaciers and icebergs, additional forms of fresh-water ice, have limited distribution in the Arctic (Figure 16). This source of water is available only around and on Greenland,[73] the islands to the west of Baffin Bay and Kane Basin, and on the northern slope of the Brooks Range.

Ground ice, frequent in permafrost areas, may serve as a source of water throughout the year. As these bodies of ice are most likely to occur in areas which favor ground-water accumulation, they are generally found at the bottom of valleys. They are often exposed, especially in summer, along stream banks where their ice is relatively easy to procure. The ice in frost mounds and pingos is available, although it may not be exposed. Such sources are not likely to be used because during the warm season fresh water is usually available and during winter most areas where ground ice is present will have other fresh-water ice or snow also available.

Salt-water Ice. Although fresh-water ice is preferred, at times salt-water ice is used. Nansen, while wintering in Franz Josef Land, used sea ice and sea water for his soup.[74] Tyson, while drifting on the ice of Baffin Bay, was able to lay

> . . . in a store of both fresh and salt water ice which can be got from different parts of the floe. The fresh has to be cut from the ponds which formed during the summer by the rain and ice melting from the high hills and hummocks and running into these depressions. The salt ice we melt to season our 'soup' or 'tea', and the fresh to drink as water.[75]

Both Nansen and Tyson used sea ice because it added salts to their food that would otherwise have been unavailable.

Sea ice may, however, be used as a source of fresh water,[76] a use that was common among many of the Eskimo groups. At Point Barrow Murdoch noticed that the natives

> . . . sometimes drank the water produced by the melting of the sea ice along the beach, and pronounced it excellent when it was so brackish that [he] found it quite undesirable.[77]

This knowledge, however, was not universal among the Eskimos, for as Birket-Smith notes:

> The Caribou Eskimos have not much opportunity of using old sea ice, the saltiness of which is washed out in the course of a year, as they practically speaking do not stay at the coast in winter. Furthermore there is little *old* pack-ice on their coast, and consequently they do not seem to know this property of the ice.[78]

According to Stefansson ". . . although some polar explorers knew that sea ice becomes fresh a large number never discovered it."[79] Others, however, after trying to use sea ice as a source of fresh water considered that there must be exceptions. Dr. James Ambler, a surgeon with De

[70] R. Collinson (ed.), "The three voyages of Martin Frobisher in search of a passage to Cathaia and India by the north-west, A. D. 1576-8," *Hakluyt Society* (1857), p. 289.

[71] *Op. cit.*, p. 231.

[72] *Supra*, p. 25.

[73] Despite the fact that the top of Greenland is an ice cap, a recent expedition there did not use ice for its water supply. It used snow instead, for, "Although snow yields much less water per unit volume than ice does, the extreme labor required to quarry ice makes snow the preferred source." Holmes, "Topographic and hydrologic studies," p. 17.

[74] E. Reynolds, *Nansen* (Harmondsworth: Penguin Books, 1949), p. 140.

[75] E. Blake (ed.), *Arctic experiences*. . . . (New York: Harper and Bros., 1874), p. 279.

[76] *Supra*, p. 40.

[77] *Op. cit.*, p. 65. Max Brewer reports that the Barrow Eskimos still gather sea ice which has piled up along the shore for their water supply. Oral communication.

[78] "The Caribou Eskimos, . . . I. Descriptive part," p. 134. Opportunity is not the only deterrent, for Jenness observed that the ". . . Copper Eskimos obtained all their water throughout the winter from snow, being ignorant apparently of the fact that ordinary sea ice loses its salinity with age, and that an old cake of the previous winter will yield perfectly fresh water." E. Weyer, *The Eskimos: their environment and folkways* (New Haven, 1932), p. 73.

[79] *The friendly Arctic*, p. 31.

Long on the *Jeannette*, was one who so considered it. He records that the crew of the *Jeannette* decided to follow the practice of utilizing sea ice after reading of its practicality in the journals of numerous explorers. However, their success at this venture was limited. Ambler wrote that he

> . . . failed to find any ice of any degree of thickness up to five feet, or ice from any pools found on the floe surface that would give a water absolutely free from salt. The snowfall was not great, and it was naturally very dry from the extreme cold; it was, of course, readily moved by the wind, and it took but a short time for it to become mingled with the loose granular ice on the surface of the floe. . . . For sometime we . . . obtained a water that was potable, but not pure, and the use of which should not be long continued.[80]

It is now generally recognized that

> The value of sea ice as a source of fresh water is directly proportional to its age, the older the ice, the lower the salinity . . . at 6 months, sea ice is brackish when melted, but potable. At 10 months, it is for all practical purposes fresh. At 2 years or more the water obtained is almost as fresh as rain water.[81]

Its value, in general, will be proportional to the ability of man to determine that sea ice which is the oldest. The physical differences between old and new sea ice, according to the United States Air Force, include differences in color, hardness, texture, and salt content.[82] Old sea ice tends to be more bluish in color, to have more rounded corners, to splinter somewhat more easily, and to taste less salty than new sea ice.[83] The oldest, and generally freshest, sea ice is usually to be found in pressure ridges which are common in all floe-ice areas. At the foot of these pressure ridges can be found frozen ponds which represent summer melt water (either from --- ice or snow) or accumulated rain water. These frozen ponds are one of the best sources of fresh water to be found away from the land.

An example of the current thinking regarding the use of sea ice as a source of water is found in the DEW Line manual which states that it should be used ". . . sparingly and only for cooking."[84]

Fluid Water Sources. While fluid water sources are the major sources during the short summer period, they are relatively unimportant during the cold season, at least, at the present time. They do, however, have a great potential, and are becoming more important every year. Although most of the rivers and lakes in the Arctic freeze to the bottom in winter, there are some on which the ice forms only a capping layer, thus maintaining a fluid condition beneath, even during the coldest portion of the year. If a means of reaching the water through the ice is available, such a source may be very valuable. Some rivers and lakes, because of varying depths of water and/or freezing, may have portions frozen to the bottom, whereas other portions will have bottom water unfrozen. Knowledge of such locations is of value to traveling parties. Hanbury illustrates such when he writes:

> We again had difficulty in obtaining water. We tried at several places with the ice chisel, and it was no easy job. After cutting through seven or eight feet of ice, it was a great disappointment to strike the dry, sandy bottom. The fact is that these rivers carry off the whole of the water which results from the melting of the snow during the summer and fall. Then they dwindle down to small creeks, so that it is hopeless to expect water except in deep pools. These appeared to be scarce. . . .[85]

Thus, the thicker the ice the less the chance of finding water beneath and the thicker the ice the more time needed for digging.

The maximum thickness of fresh-water ice is generally considered to be about eight feet. It does not necessarily follow, however, that any lake or river over eight feet deep will be of value as a winter source, because sediments may reduce the quality. Quality may also be affected because of stagnation. As a result of the capping ice, there is a lack of natural mixing, especially in non-spring-fed lakes, causing a decrease in the oxygen content. Freshness is frequently absent.[86] A recent study of lake water in the Barrow area indicates that the chemical composition of such water is correlated with ice thickness, the impurities increasing with increasing ice thickness. Although

[80] As quoted in Hostrup, Lyons & Associates, *op. cit.*, p. 7.

[81] Eisberg and Owens, *op. cit.*, p. 73.

[82] *Survival* (Washington: 1945), U.S.A.F. Manual No. 64-5, p. 36.

[83] Many authors believe that the ability to distinguish the freshest sea ice, without tasting, is limited to the Eskimos. See, for example, Edward Shackleton, "A winter in latitude 78° N.," *Scottish Geographical Magazine*, LIII (1937), p. 239.

[84] Western Electric Company, *op. cit.*, p. 101.

[85] *Op. cit.*, p. 134.

[86] Hanbury writes that "It took us a long time in the evening to find water, but eventually discolored and not very palatable water was struck seven and a half feet below the surface of the ice." *Ibid.*, p. 135.

> . . . a lake might be low in chlorides, hardness, and other minerals during the ice-free period, it may be necessary to carry out extensive water treatment during the season when the lake ice increases in thickness.[87]

Brewer states that besides this spring concentration there are two other times in the year when water contamination may be expected. One time is in early summer as a result of surface runoff due to snow and ice melt and the other occurs in the fall after the first freeze. As soon as the ice freezes, animals, in using the ice as a runway, drop their feces on it. During the early part of the freeze-season the ice may form and melt several times before a permanent cap is made and as a result feces are added to the water, contaminating it.[88]

The importance of sub-ice lake water as a winter source is limited, for many of the lakes probably could not furnish enough for more than a few people.[89] Although lakes are numerous, they are shallow and small and may be deceiving "... in that they are principally the result of retarded drainage through the permafrost rather than evidence of a large source of water."[90] However, in many areas today, lakes are meeting the demand which in most instances is not great. To the present, only a few of the lakes of the Arctic have been checked as to depth, water quality, re-supply capabilities, and other factors.

Several other conditions affect water availability in the Arctic. High permafrost level prevents deep water penetration while sparse vegetation hinders water movement only slightly. Thus, runoff is rapid which, coupled with low precipitation, accounts for the small storage found over vast areas. Artificial storage, as by dams, will be necessary in most regions in order to provide a continuous supply of water for all but the smallest of settlements.

Fresh water is available during the winter wherever springs maintain themselves throughout the year. Such springs in the north usually have their sources within or below the permafrost. They are, then, relatively rare in the area north of the tree line where continuous permafrost extends to great depths. Springs of this type may contain highly mineralized water and therefore be of limited value.[91] Permanent springs will generally be surrounded by ice mounds and topped by steam in cold weather. A spring having an outlet under a river or lake may be sufficient to maintain part of the river or lake unfrozen during part, or all, of the cold season.

Muller, in discussing Russian experiences with permafrost, notes that large icings[92] ". . . from which water flows, or may be induced to flow, throughout the winter may be utilized or developed as dependable sources of water supply."[93] Although frost mounds, pingos, and other types of swellings are indicative of the presence of water, they are not necessarily good water sources. The smaller types of swellings have water that does not flow in the winter. Pingos, the largest and most permanent of the swellings to be found in the Arctic, are potential water producers. Water is usually found in the fissures radiating from the breached crater (Figure 12).

Another source of fresh water was unexpectedly discovered by the group who first occupied one of the ice islands (T–3) in the Arctic Ocean. While studying the vertical structure of the ice, they once drilled into a fresh-water lake at a depth of eight feet. Rodahl states that "This 'underground' lake, formed by melted water accumulated in a trough between two ridges, gave us a supply of drinking water."[94] This type of lake, in many respects, resembles more a lake found on land than it does a pond formed between hummocks of sea ice. Even on sea ice, though, fresh water may be found during much of the winter. On sea ice, irregularities often cause the accumulation of drift snow to several feet in depth. This snow acts as an insulation protecting the ice beneath. If it happens to lie over a hollow which contains water, it will prevent freezing of this water for several months. Fresh water, thus, can be obtained by chiseling a hole through the ice to the water beneath.[95]

Permafrost and Ground Water. Most students believe that deep wells are necessary before large demands for water can be met in the Arctic, as surface water is locked in the solid state by seasonal change in temperature and sub-ice lake wa-

[87] W. Boyd, "Limnology of selected arctic lakes in relation to water supply problems," *Ecology*, XL (1959), p. 51.
[88] Oral communication.
[89] Alter, *op. cit.*, p. 223.
[90] *Idem.*

[91] Muller, *op. cit.*, p. 27.
[92] *Supra*, p. 45.
[93] *Op. cit.*, p. 27.
[94] "Ice islands in the Arctic," *Scientific American*, CXCI (1954), 44. See also A. Crary, "Arctic ice island and ice shell studies," pp. 30 and 41.
[95] Stefansson, *Arctic manual*, p. 241.

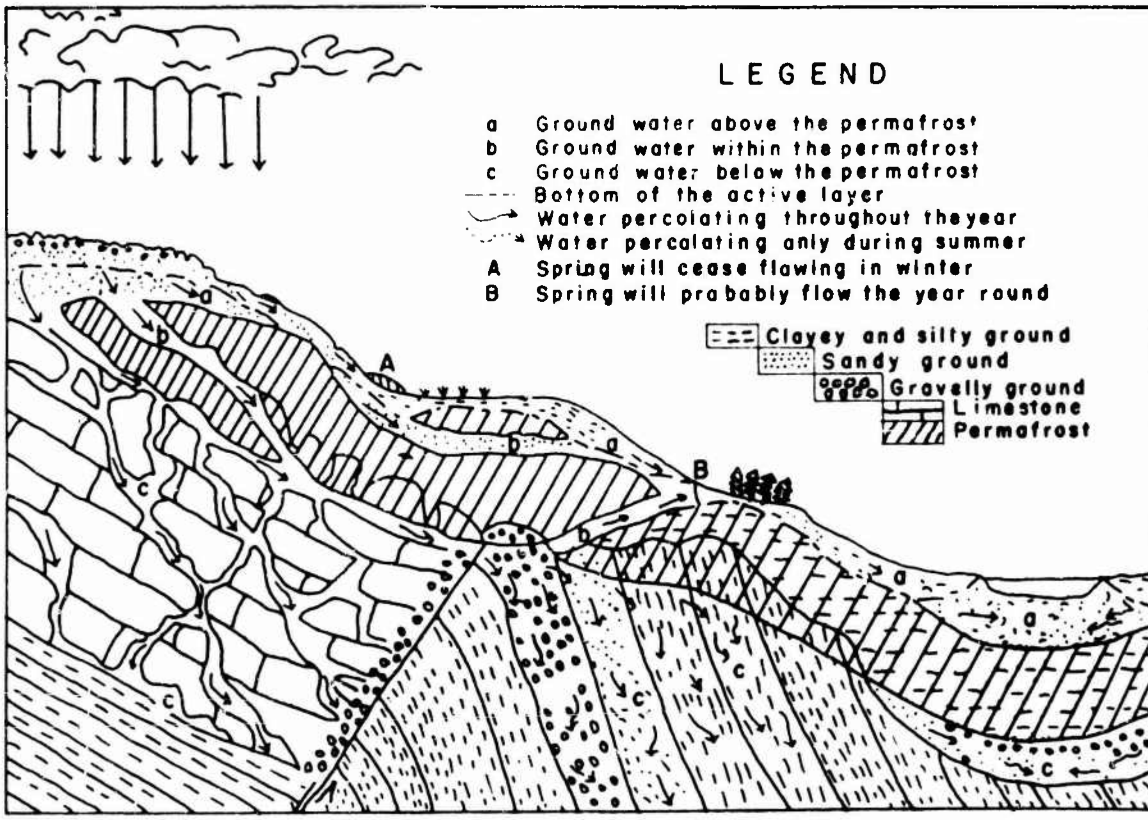


Figure 17. Ground water as related to permafrost. Adapted from Muller, op. cit., *p. 23.*

ter is not adequate in most areas for a large consumption. However, no successful deep wells have been drilled in the Arctic to date.

Permafrost is one of the factors affecting the development of a supply of water from wells. Muller devotes one section of his book to a discussion of water supply. His classification of ground water found in permafrost areas follows:

A. Ground-water from springs

B. Suprapermafrost water (water supply from above the permafrost)

C. Intrapermafrost water (water supply from within the permafrost)

D. Subpermafrost water (water supply from below the permafrost)

1. Alluvial
2. Layered
3. Fissured
4. Solution channels"*

*Op. cit., p. 132

The situations under which each of these types of water-bearing strata occurs are schematically illustrated in Figure 17.

Although all of the types of water in Muller's classification are available in many localities in the North, all are rare or at least very expensive to develop under the prevailing conditions. Exceptions include portions of the large river valleys (notably the Mackenzie), larger lakes, and the portions of the Barren Grounds that may fall in the belt of discontinuous permafrost. Such distributions are imperfectly known, but their precise delineation would be invaluable to the development of a better water supply.

The farther one moves from the zone of continuous permafrost the easier it is to utilize ground water efficiently. This condition is as true for suprapermafrost water as it is for intrapermafrost and subpermafrost water. Along the northernmost coasts continuous permafrost of varying depths (up to at least 1,000 feet) and a shallow active layer limit ground water to zones below the permafrost or to a very shallow layer above the permafrost table in summer. Thus, probably the only reliable source could come from sub-permafrost aquifers. However, "In the Arctic coast communities of Alaska, wells which have been drilled to a point below permafrost have produced only salt water."[97] Although the deep wells drilled in the Fairbanks area have produced adequate water (with a high iron content), it does not follow that deep wells along the coast will produce the same.

There are many different situations occurring within the several types of permafrost which influence water availability. Often, within the permafrost, there are found unfrozen zones, many of which may be water bearing.[98] The frequency and size of these unfrozen zones increase along a line extending from the zone of continuous permafrost through that of discontinuous into the zone of sporadic permafrost (Figure 10). These unfrozen zones may be man made. At Kotzebue, heated buildings have created thawed areas deep enough to contain wells.[99]

Permafrost varies in its relationship to rivers and lakes. If these water bodies do not freeze to the bottom in the winter, there is a part of the ground beneath that is not permanently frozen. Under some of the larger lakes and rivers, even in the zone of continuous permafrost, there are probably islands of unfrozen ground. The depth of these basins or bowls undoubtedly varies from zero to a maximum determined by the maximum depth of the permafrost. Such localities, especially in the extreme north, may become very valuable as sources of water, for they offer the best possibilities for the establishment of functional wells. A similar situation might prevail at no great distance from the coasts on the continental shelf. How far permafrost extends out under the oceans has, as far as can be determined, never been calculated.

The active layer may be utilized at times as a source of water. It varies greatly in thickness but generally increases with decreasing latitude. Along the coast (as in northern Alaska) it is apparently less than two feet thick. The active layer, as such, is only a poor source of impure water at best.

There are locations where the active layer does not reach to the top of the permafrost, leaving a continuously unfrozen layer (called "talik" by the Russians) between the perennially frozen permafrost and the seasonally frozen active layer (Figure 10). Water is available frequently in this layer. However, it is probably of no great value north of the tree line except possibly near large lakes and rivers.

Permafrost is also significant in factors of water supply other than availability. Permafrost may isolate unfrozen zones and effectively trap water for long periods of time with detrimental results to quality. In areas of continuous permafrost, as water is prevented from penetrating into the ground, there may develop ". . . a concentration of organic acids and mineral salts in suprapermafrost water."[100]

[97] Alter, *op. cit.*, p. 224.
[98] Black, "Permafrost as a natural phenomenon," p. 3.
[99] D. Cederstrom, P. Johnston, and S. Subitzky, *Occurrence and development of ground water in permafrost regions* (Washington: U. S. Government Printing Office, 1953), Geological Survey Circular 275, p. 8.

[100] Black, "Permafrost as a natural phenomenon," p. 8.

Water Production, Processing, and Storage in the Arctic

Melted snow and ice, surface and subsurface water, and rain water are all more or less available in the Arctic. All of these sources have been and/or are being used. At present ". . . melted ice and snow are the most common sources of water for domestic and household purposes."[101]

[101] Alter, *op. cit.*, p. 219.

The Eskimos

In pre-contact days water was used by the Eskimos for little other than drinking and cooking. All uses required little water. As the Eskimos lived in family units, each quite self-sufficient, water was procured on a family basis or individually. This latter condition prevailed when individuals were away from the family, for example, on hunting trips.

All of the sources discussed above were apparently used by the Eskimos, except the deep well (that is, subpermafrost or intrapermafrost water). Although the first recorded technique used by the Eskimos in quenching thirst was that of eating ice, it does not follow that this method was their most important one. As a matter of fact, it appears that this procedure was relatively rare.

Summer Supply. During the summer, the Eskimos obtained their water at the nearest pond, lake, or river, with relatively little thought of quality. There are exceptions, however. Birket-Smith records that at Eskimo Point

> . . . one saw the strange scene of the men putting over to the other side of the open channel in their kayaks and making their way a good distance over the ice to a hole where the water was better.[102]

Despite such occasional incidents, the idea of quality was not imbedded in the Eskimos to the same extent as in the whites. Thus, it is probable that little ice was melted by the Eskimos during the summer even where it was available, for under natural conditions of thaw there would be fresh-water ponds on the ice floes, as well as on the tundra. There is no evidence that any of the Eskimos stored ice for use as a summer water source in pre-contact days. This technique would have necessitated a somewhat more permanent settlement in the summer than most Eskimos enjoyed.

Today, possibly because of the influence of outsiders,

> . . . Eskimos in northern Alaska sometimes obtain summer water supplies from small wells dug into the permafrost which accumulates water from melting permafrost or ground ice.[103]

Also, some Eskimos today store ice to be melted during the summer, a technique that has been made possible by the development of more-permanent habitations.

Winter Supply. *Techniques Used in Settlements.* During the cold season, snow and ice are found nearly everywhere, so it is generally unnecessary to go great distances to acquire it. Because ice and snow, under the best conditions for

[102] "The Caribou Eskimos, . . . I. Descriptive part," p. 133.
[103] Hopstrup, Lyons & Associates, *op. cit.*, p. 16.

Figure 18. Blocks of lake ice to be melted for drinking water.

their use as water, are compact as well as solid, a leak-proof container is not a necessity. It is thus relatively easy, in most areas, to gather a dogsled load of ice or snow and to store it near the igloo's entrance (Figure 18). The location usually used for such storage is on the lee side of the dwelling,[104] to prevent its being covered with snow.

The critical factor in winter is not the availability of snow or ice but rather the availability of a means of converting it into the liquid state and keeping it that way. In pre-contact days all of the heat used in heating their homes, as well as that used in cooking and in melting snow or ice, was produced by blubber lamps, with few exceptions.[105] The great importance of the lamp is emphasized by Hall in his statement that

> . . . without the *lamp*, Esquimaux could not live —not so much because of its warmth or use for cooking, but because it enabled them to dry their skin clothing, melt ice for drink, and gives them light during the long arctic night of winter.[106]

For many groups the most important function of the lamp was the melting of ice or snow and for some this was the only function at certain times of the year. For example, the Mackenzie Eskimos used their lamps exclusively for this purpose so long as the stock of half-rotted fish and meat they had obtained the previous summer lasted.[107]

[104] R. de Coccola and P. King, *Ayorama* (Toronto: Oxford University Press, 1955), p. 13.
[105] The one major exception to the importance of the blubber lamp is found among the Caribou Eskimos. Birket-Smith, in "The Caribou Eskimos, . . . I. Descriptive part," states that the ". . . *blubber lamp is hardly known at all and even those who have one scarcely ever use it for cooking*," p. 88. Such an instance is quite exceptional, for, as Birket-Smith also writes, the blubber lamp is the ". . . central point of the indoor life . . . from Greenland to Alaska." *Ibid.*, p. 92.
[106] *Arctic researches and life among the Esquimaux* (New York: Harper and Bros., 1865), p. 175.
[107] Stefansson, *The Stefansson-Anderson arctic expedition*, p. 13.

Figure 19. Snow melter at Anoatok, Greenland. From Kane, Artic explorations: . . . , *I, p. 381.*

Figure 19 is a reproduction of Kane's drawing of a type of snow melter used by the Polar Eskimos of Greenland. He describes this melter as follows:

> A flat stone, a fixture of the hut, supported by other stones just above the shoulder-blade of a walrus, —the stone slightly inclined, the cavity of the bone large enough to hold a moss-wick and some blubber: —a square block of snow was placed on the stone, and, as the hot smoke circled around it, the seal-skin saucer caught the water that dripped from the edge.[108]

Although direct melting was common, melting through the use of space heat was widely used. During winter the Barrow Eskimos use this method by placing a ". . . lump of clean snow on a rack close to the lamp, with a tub under it to catch the water that drips from it."[109]

With the limited amount of heat available, water was seldom over-abundant. While all groups melted ice and snow for water, most also used river or lake water as long as possible and some throughout the winter. Figure 20 illustrates the relative importance of the various sources of water used among Eskimo groups during the winter. The Caribou Eskimos depended upon sub-ice lake water to a much greater extent than any of the other Eskimos. Birket-Smith notes that they prefer to build a camp ". . . by a lake where fresh water and fishing through holes in the ice are available."[110] One of the Rasmussen's informants told him that the Utkuhikjalingmiut, who live in the Back River area,

> . . . always have water from the lakes. Our country is so situated that we can always build our snow huts near a lake. There we keep a hole open, covering it over with snow so that the water does not freeze inside, where only a little thin ice forms between the times when we draw water from it. Thus we are always able to drink when we are thirsty.[111]

These water holes are not only kept open but are made more functional, for

> At the hole, one of the inhabitants of the place leaves an ice pick and an ice scoop behind for the use of the next comer, as new ice always forms over the hole. The long handles on these implements are easily recognizable signs at the waterholes.[112]

Commonly, water holes were protected by snow huts built over the opening in the ice.[113]

The Mackenzie Eskimos, in contrast to the Caribou Eskimos, usually prepared water over lamps, but ". . . those who lived on lakes or rivers sometimes cut holes in the ice for water with the ice pick."[114]

Storage of water in the liquid state was a problem because containers had to be leak proof. In former times vessels of tightly sewn skin were used, some of which were quite large. The importance of the skin container is emphasized by Kane who, in discussing the Anoatok Eskimos of Greenland, stated that "A rude saucer shaped cup of sealskin, to gather and hold water in, was the solitary utensil that could be dignified as table furniture."[115] Schwatka writes that the seal-skin bucket

> . . . holds from two quarts to double as many gallons, and is generally made large, so that its contents will not freeze solid during the night. . . . When empty of water, and clogged with ice (as it usually is when they start to the ice-well to refill it), it is given a vigorous beating over a sledge, a hard snowdrift, or, if in a sportive mood, over a dog's head, the broken ice-splinters flying in every direction, leaving it as limber as a piece of canvas.[116]

In more recent times, metal and wooden vessels of varying shapes and sizes have been acquired. Crantz, in his observations of the Green-

[108] *Arctic explorations* . . . , I, p. 381.
[109] Murdoch, *op. cit.*, p. 64.
[110] "The Caribou Eskimos, . . . I. Descriptive part," p. 73.

[111] "The Netsilik Eskimos," p. 487.
[112] Birket-Smith, "The Caribou Eskimos, . . . I. Descriptive part," p. 133.
[113] Rasmussen, "Observations of the intellectual culture of the Caribou Eskimos," p. 45.
[114] Stefansson, *The Stefansson-Anderson arctic expedition*, p. 133.
[115] *Arctic explorations* . . . , I, p. 382.
[116] "The implements of the igloo," p. 85.

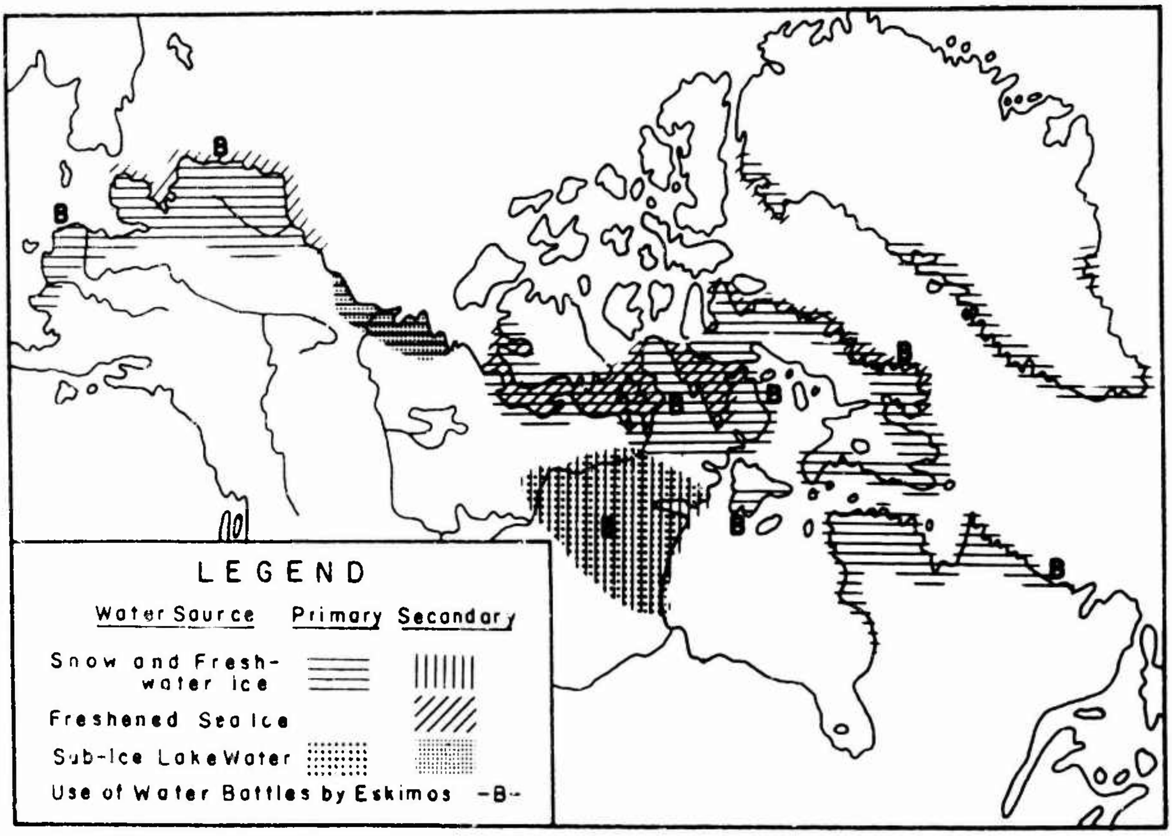


Figure 20. Primary and secondary sources of water among the Eskimos during winter.

land Eskimos at Disko, had the following to write:

> Their drink is clear water, which stands in the house in a great copper vessel, or in a wooden tub which is very neatly made by them. . . . They bring in a supply of fresh water every day in a pitcher, which is a seal-skin sewed very tight, . . . and that their water may be cool, they chose to lay a piece of ice or a little snow in it, which they seldom want.[117]

The same basic type of water tub is used by the Ammassalingmiut Eskimos in east Greenland but, in contrast to the Disko tub, it is

> . . rarely filled by fetching the water in a bucket . . from a river, but as a rule by being filled with large pieces of ice or frozen snow which slowly melt in the heated air of the house or tent.[118]

Similarly, the Koyukuk keep a large wooden barrel filled with snow which melts from the heat in their homes.[119]

[117] *The history of Greenland*, I, p. 144.

[118] W. Thalbitzer, "Ethnographical collections from East Greenland (Angmagsalik and Nualik) made by G. Holm, G. Amdrup and J. Petersen," in W. Thalbitzer, "The Ammassalik Eskimo," *Meddelelser om Grønland*, Bd. 39 (1914), p. 552.

[119] R. Marshall, Arctic village (New York: Literary Guild, 1933), p. 155.

Drinking tubes appear to have been an accessory among all of the Eskimo groups.[120] Birket-Smith observed that in Greenland

> As a rule the water pail is filled with ice or frozen snow in winter, and in order to suck up the water gathering at the bottom, the Angmagssalik Eskimos use sucking tubes of wood or bone; regular water dippers are also used[121]

The drinking tube is also used for drinking water from ice-covered pools[122] and, in the spring, from pools formed under the snow.[123] The drinking tube forms part of the traveling equipment of many groups.

Techniques Used while Traveling. When traveling, the method of procuring water by the Eskimos is basically the same as when in a village, that is, by melting snow or ice or by digging

[120] Birket-Smith, "Ethnographical collections from the Northwest Passage," *Report of the fifth Thule expedition*, 1921-24, VI, No. 2 (1945), p. 224.

[121] Birket-Smith, "The Greenlanders of the present day," *Greenland* (London, 1928), p. 90.

[122] Mathiassen, "Material culture of the Iglulik Eskimos," *Report of the fifth Thule expedition*, 1921-24, VII, No. 1 (1928), p. 155.

[123] Boas, *The Central Eskimo* (Washington: U. S. Bureau of American Ethnology, Sixth annual report, 1884-85, pub. 1888), p. 535.

through a capping layer of ice to fresh water beneath. The technique of melting ice or snow on the trail occasionally takes unique forms. One recorded method proceeds as follows:

> When he grows thirsty, he halts; scrapes away the snow until he lays bare the solid ice beneath; and painfully scoops in it a small cavity. Next, he fetches a block of fresh-water ice from a neighbouring berg, lights his lamp, and, using the blubber for fuel, proceeds to place the block on the edge of the cavity. As it slowly thaws, the water trickles down into the hole, and when the Eskimo thinks the quantity collected is sufficient to quench his thirst, he removes the crude apparatus, and, stooping down, drinks the soot-stained fluid.[124]

Another technique of melting snow was observed by John Ross while on a musk ox hunting trip with a Boothia Peninsula Eskimo. After a musk ox had been killed the hunter, who had been without "refreshment" for eighteen hours, ". . . was content with mixing some of the warm blood with snow, thus drinking as much as he required to quench his thirst, . . ."[125]

Many groups, in order to conserve fuel, prefer to dig through river or lake ice for water. Schwatka has discussed this technique thoroughly, emphasizing not only the tools but also the knowledge that enabled the Eskimos to be most proficient in this important task. His observations are quoted at length below:

> In a river the native is not a bad judge of the places where he will find the swiftest currents even under the ice, and here he knows that the glacial covering is thinnest. Any snow banks or drifts that have formed by the wind before the temperature in the winter reached its minimum, will give thinner ice, and consequently less work; for the snow can be shovelled off in two or three minutes, even from the deepest drifts. If these drifts should be covered with a crust, the native at once knows that they were formed during the October or November thaw, before the ice could have been very thick; and a couple of feet of drift will save him digging through nearly double that amount of ice. And with many of these savage traits bordering on instinct, he can closely judge about the age of the drift; for, if made since the coldest weather, it has been no protection to the ice-covering, and only adds the labor of removing it, slight as it is. Where there is no covering to the clear blue ice, you will often see them extended full length, their little pug noses pressed against it; for they can, by varying peculiarities of the hues, tell if it be frozen to the bottom, or not. The site selected by all these conditions duly weighed, the operation is commenced by starting a hole about a foot and a half in diameter, and probably a foot deep, with the ice-chisel. In cutting with this, the ice has been broken up into small fragments; and these are taken out with the ice-scoop, and this alternation kept up until water is reached.[126]

The length of time needed to dig an ice well varies with the thickness and nature of the ice as well as with the skill of the well digger. A skilled Eskimo can cut through seven feet of ice in less than an hour.[127] Ice wells are not always successful, and when the Eskimos were ". . . extremely anxious to economize oil, . . six or seven wells were dug before they gave it up or were successful"[128]

Not all under-ice water is obtained by the Eskimos from rivers and lakes, for early in the cold season fresh water can often be found among sea-ice hummocks. Kane reports one such instance in which Myouk, his Eskimo companion,

> . . . began climbing the dune-like summits of the ice-hills, tapping with his ice-pole and occasionally applying his ear to parts of the surface. He did so to three hills without result, but at the fourth he called out, "Water!" . . . A few minutes' digging brought us down to a scanty infiltration of drinkable water.[129]

While traveling much time was required to melt ice with the blubber lamp or to dig through several feet of ice. As a result, some of the Eskimos

> . . . formerly (as for instance we know of the Aivilingmiut) carried a kind of field-bottle in their bosom, so that the water could remain thawed from the morning. The fact that some well-to-do Eskimos now have a thermos flask also indicates this.[130]

Samuel Hutton noted that his sled drivers on one trip carried water in a sealskin bag which they stored under a doubled-up bearskin on the sled.[131] Other materials used in the construction of these bags include the stomachs, bladders, and intes-

[124] *The arctic world: its plants, animals and natural phenomena* (London: T. Nelson and Sons, 1876), p. 195. This book, although based on original journals, has some apparent misstatements. Whether the above has been altered from the original has not been determined.

[125] *Narrative of a second voyage . . .*, p. 228. Whether this practice had ritual significance, as well, was not stated.

[126] "The implements of the igloo," p. 83.

[127] *Ibid.*, p. 84. See also W. Gilder, *Schwatka's search: sledging in the Arctic in quest of the Franklin records* (New York: C. Scribner's Sons, 1881), p. 204.

[128] Schwatka, "The implements of the igloo," p. 84.

[129] *Arctic explorations. . . .*, I, p. 427.

[130] Birket-Smith, "The Caribou Eskimos, . . . I. Descriptive part," p. 178.

[131] *Among the Eskimos of Labrador, a record of five years' close intercourse with the Eskimo tribes of Labrador* (London: Sealy Service and Co., 1912), p. 123.

tines of reindeer, seals, whales, and walruses,[132] and, according to Brewer, the flippers of seals.[133] These bags vary greatly in size, some being small enough to be carried beneath a parka, others large enough to hold several quarts.[134] As these bottles are frequently filled with snow, they serve for water production as well as for transportation and storage. The groups which have been reported as using water bags are shown on Figure 20.

The Indians were not so well prepared to cope with the natural aspects of their water supply as the Eskimos, especially when they were in the tundra away from the trees which make up such an important part of their normal environment. Hunbury, who spent some time with both the Eskimos and Indians, mentions that those Yellowknife and Dog Rib Indians who ventured out onto the tundra in search of musk ox suffered greatly from thirst.

> They carry no ice-chisel for making holes through the ice to procure water. When the small stock of wood which they carry comes to an end, they are without fire, and cannot even melt snow and ice for drinking-water. They have then to eat snow or suck ice the whole day long, in order temporarily to satisfy the unassuageable thirst with which one is consumed when traveling fast in very cold weather.[135]

The Eskimos of today solve their water problems by the same basic techniques they used in pre-contact days. Their needs are greater, but the sources have changed little. In summer they still dip water from the numerous lakes in the active layer; during winter, as in times past, they depend upon water from under lake and river ice and from ice and snow. However, ice and snow are likely to be hauled to the settlements by weasel, jeep, or truck as well as dogsled. Their storage containers are now commonly metal and often much larger than those made of sealskin. The 55-gallon oil drum is a common form of container today. The melting of ice generally is accomplished on a large stove (again, often made from an oil drum) burning petroleums, drift wood, or coal. Blubber today is normally used only when no other fuel is available. Native travelers now, more often than not, use the kerosene Primus with a metal pot for melting ice. This combination has reduced the time required for water preparation to a fraction of that needed under aboriginal conditions.

The Explorers

The first explorers to penetrate arctic waters were little hampered by a water problem. In fact, they probably benefited by arctic conditions, at least in comparison with their contemporaries sailing in tropical waters. As the first arctic explorers sailed only during the summer, they had, if they landed on shore, water available in the liquid form. Even more important, however, was the fact that these early navigators were able to refill their water casks from ice-bergs and floe ice, a source not available in temperate and tropical oceans. Davis, in 1585, wrote that

> . . . we met Islands of yee floating, which had quickly compassed us about: then we went upon some of them, . . . before night we came aborde with our boat laden with yee, which was very good fresh water.[136]

Koldewey, nearly 300 years later, wrote:

> We therefore lay-to, and as there was a large floe close to us, with several pools of water upon it, we landed in order to renew our store of fresh water, which was nearly exhausted. This was the first time during the voyage that we had set foot on the ice. . . .[137]

The techniques used in re-watering ships from ice floating in the ocean were quite varied and often included most of the crew. Koldewey tells of the bucket-brigade method his crew used in the following statement:

> When our scientific observations were over we joined the row of water-bearers, forming two lines along which the full and empty buckets were merrily passed, but it was midnight before our task was done and we returned to rest.[138]

A somewhat more refined technique was employed by the whalers, who, "From the cavities

[132] E. Nelson, *The Eskimo about Bering Strait* (Washington: U. S. Bureau of American Ethnology, Nineteenth annual report, 1896-97, pub. 1899), p. 73.

[133] Oral communication.

[134] Nelson, *loc. cit.*

[135] Hanbury, *op. cit.*, p. 79. Such a predicament resulted despite the fact that each hunter filled his sled ". . . to capacity with selected firewood cut to uniform length and used solely to melt ice for drinking purposes and to boil meat and tea." J. Mason, "Notes of the Indians of the Great Slave Lake area," *Yale University Publications in Anthropology*, XXXIV (1946), p. 20. As long as their wood lasted, they drank snow water. Russell has described the method used by the Indians in making snow water. "Each individual carried a tin plate on which a block of snow was placed and inclined toward the fire. As the lower side became saturated, we drank the water as from a soggy snowball. . . ." *Explorations in the far North* (University of Iowa, 1898), p. 115. He also writes that in the woods they had better techniques. For example, the Indians would melt ". . . snow by fixing large blocks on the ends of poles before the long camp fire, a steady stream soon trickled from the lower end which was trimmed to a point by a few strokes of a knife." *Idem.*

[136] As quoted in A. Markham, *op. cit.*, p. 4.

[137] *Op. cit.*, p. 267.

[138] *Ibid.*, p. 268.

of these icebergs, . . . are accustomed, by means of a hose, or flexible tube of canvas, to fill their casks easily. . ."[139]

This source is still being used by ships in polar regions and, according to Foster, should be utilized to an even greater extent. He contends that, as it is necessary to conserve fuel where a ship is liable to be beset by ice, an economical source of water is desirable. In arctic waters such a source is available and, in order to utilize it today, Foster believes that a small hand pump would be adequate for a small vessel whereas a large ship would require a power-driven pump.[140]

At sea, when icebergs or floes do not have water of sufficient quantity or quality, ice itself may be collected. If ice floes are used, the best ice comes from those floes which have been under pressure. By placing this ice in a steam-heated tank for melting, more water will be produced from a given quantity of fuel than if the same amount of fuel should be used in distilling salt water.[141] Nonetheless, icebreakers and other Navy ships in the Arctic Ocean distill salt water for their needs.

It was not until explorers began to winter in the Arctic that they first had to cope with an arctic water problem. James, one of the first to spend such a winter, illustrates well the general characteristics of the natural problem as well as the European background used in solving such a problem. He states that in October, at his wintering place on the western shore of Hudson Bay,

> The Ice Beere, being thaw'd in a kettell, was not good, and they did breake the Ice of the pondes of water to come by water to drinke. This pond water had a most lothsome smell with it, so that, doubting lest it might be infectious, I caused a Well to be sunke neere the house. There we had very good water which did taste (as we flattered ourselves with it) even like milke.[142]

By December his well was frozen, so James, believing snow water to be "very unholesome," sent three of his men to a spring he had discovered when they first landed at a distance of about three quarters of a mile from their house. These men

> . . . wading thorow the snow, at last found the place; and shoueling away the snow, they made way to the very head of it. They found it spring very strongly, and brought [James] a Can of it, . . . This spring continued all the yeere, and did not freeze but that we could breake the Ice and come to it.[143]

Figure 21. Melting snow and cooking in the house in which Barents wintered on Novaya Zembla. Gerrit de Veer, op. cit., p. 128.

Soon after the explorers established a wintering site, routines for all personnel were established. One of the most important assignments was that of maintaining a daily water supply. Munk, for example

> . . . made regulations for keeping a watch, the fetching of wood, and burning of charcoal as well as with regard to whose duty it was to be, during the day, to melt snow into water; . . .[144]

Thus, Munk, unlike James, used snow as a source of water, even though he considered thawed and boiled beer better than snow water.[145]

Some of the early exploration parties spent the winter in specially constructed houses on land,[146] whereas others converted their ships into winter quarters. This latter practice became the general method being extensively used in the nineteenth century.

Ships in the sixteenth century were equipped with a cooking place (*caboose*) on the deck

[139] [illegible] New York: J. and J. Harper, 1831, p. 29.
[140] L. Foster, "Water [illegible]," [illegible] VII (1954), p. 52.
[141] *Idem.*
[142] [illegible]
[143] *Ibid.*, p. 528.
[144] Gosch, op. cit., p. 29.
[145] *Idem.* Other winterers, like Munk in using snow, even if not relishing it, mention it frequently and occasionally with a sense of humor. Barents, telling of his wintering in Novaya Zembla in 1597, mentions that ". . . we drank water, which agreed not well with the cold, and we needed not to coole it with snowe or ice, but were forced to melt it out of the snow." G. de Veer, "The three voyages of William Barents to the arctic regions (1594, 1595, and 1596)," *Hakluyt Society*, LIV (1876), p. 128.
[146] For example, Barents in Novaya Zembla and James on Hudson Bay had houses on land. The first instructions for wintering within the American Arctic were issued to Martin Frobisher by Queen Elizabeth in 1578. She wrote: "Yf yt be possible, you shall leave some persons to winter in the straight. . . ." Frobisher's subsequent plans called for the establishment of a colony of 100 people to be left with supplies to last eighteen months. A house had been made to order, but during a storm one of the barks carrying sections of it sank. Frobisher, on determining the extent of the loss, decided it was futile to establish the colony the Queen had ordered. The full account is found in Collinson, op. cit., p. 119.

Figure 22. Snow melter on board ship. Kane, The U. S. Grinnell expedition in search of Sir John Franklin *(New York: Harper and Brothers, 1854), p. 233.*

which burned wood and coal. These cabooses were taken below if the temperature became too low.[147] In the dwellings on land an open fire with chimney was the common method used. Over the fire was placed a kettle for melting snow (Figure 21) Space-heat melting was also used extensively, although many accounts mention that within a few feet of the fire water froze. James, describing his wintering on Hudson Bay, emphasizes this fact as follows:

> The Cookes Tubs, wherein he did water his meate, standing about a yard from the fire, and which he did all day plye with melted Snow-water, yet, in the night season, whilst he slept but one watch, would they be firme frozen to the very bottome.[148].

One technique used to counter the cold temperatures next to the floor was practiced by Kane on board his ship where " . . . the carlines overhead are hung with tubs of chopped ice, to make water our daily drink."[149]

When great numbers of explorers were wintering during the nineteenth century there was much experimenting with snow-melting equipment to be used on board ship. Koldewey constructed in the

> . . . chimney of the caboose . . . a receiver, from the bottom of which a pipe ran through the deck into a barrel, and all snow thrown into the receiver, being melted by the warmth of the chimney, fell into it.[150]

A similar arrangement, devised by Kane, is illustrated in Figure 22.

Once winter ceased being just a period of time wasted while waiting for the sea to reopen, and became instead a time to prepare for and engage in sledge explorations, other water problems presented themselves. Sledge travel, in order to be successful, whether man or dog powered, necessitated the conservation of weight. A heavy fuel load worked against effective sledging.

In the early days of arctic sledging by explorers, the date of starting often depended on the availability of water. Lyon delayed the start of his sledging season in April, 1822, by several days, because the temperature was not

> . . . sufficient even at noon, except on occasional days, to thaw ice, or to afford us a draught of water, without which we could not travel; and as we were to carry twenty day's provisions, it was not in our power to take much wood for thawing snow.[151]

Kane, thirty years later, notes the same result, that is, a saving of weight, because

> The snow was sufficiently thawed to make it almost unnecessary to use fire as a means of obtaining water: they could therefore dispense with tallow or alcohol, and were able to carry pemmican in larger quantities.[152]

The main difference between Kane's and Lyon's experience is that Kane saved weight by not carrying tallow or alcohol whereas Lyon saved it by leaving wood behind.

By the middle of the nineteenth century, not only had some of the explorers replaced wood with alcohol as a fuel, but many also began utilizing Eskimo techniques. Kane, in 1855, stated that his

> . . . plans for sledging, simple as I once thought them, and simple certainly as compared with those of the English parties, have completely changed. Give me an eight-pound reindeer-fur bag to sleep in, an Esquimaux lamp with a lump of moss, a sheet-iron snow-melter or a copper soup-pot, with a tin cylinder to slip over it and defend it from the wind. . . .[153]

Kane frequently melted water in a kettle hung on a tripod over a fire, a technique he used in his ship as well as in the field.[154] He used an Eskimo lamp as an accessory, for " . . . it helps out the

[147] Munk used another technique. He had large fireplaces built on around which some twenty people could gather for warmth. Gosch, *op. cit.*, p. 27.
[148] Christy, *op. cit.*, p. 536.
[149] Kane, *Arctic explorations* . . . , I, p. 173.
[150] *Op. cit.*, p. 319.

[151] *The private journal of Capt. G. F. Lyon*, . . . (London: J. Murray, 1824), p. 191.
[152] *Arctic explorations:* . . . , I, p. 238.
[153] *Ibid.*, II, p. 16.
[154] *Ibid.*, I, pp. 218 and 442.

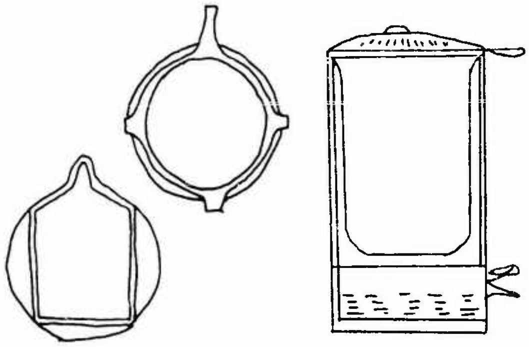


Figure 23. Cooking apparatus developed by Kane.
Kane, Arctic explorations: . . . , *II, p. 173.*

Figure 24. Payer's special cooker inside tent.
Payer, op. cit., *p. 279.*

cooking and water-making, without encroaching upon our rigorously-meted allowance of wood."[155] However, in making extensive preparations for sledging to safety in May, 1855, Kane had his best metal worker make a special cooking apparatus which he considered the most important item in their equipment.[156] This special cooker (Figure 23) consisted of an iron cylinder eighteen inches high and fourteen inches in diameter placed over an iron saucer, in which was placed blubber.[157] The cylinder defended the lamp from the wind and held tin vessels used in melting snow above the lamp.

As sledging became more important, much thought was given to the construction of a heater which would ". . . render combustion as complete as possible and let none of the heat escape till it has done its work."[158] Although these heaters were not made exclusively for snow or ice melting, this task was one—and invariably the first—function the heater served after being fired up. Their efficiency was often judged by the speed with which they could convert a given amount of ice or snow into water.[159]

These "cooking machines" were all basically similar in that they incorporated two or more pots so arranged as to get the maximum benefit of the heat. The one developed by Payer for his 1872–74 expedition to Franz Josef Land has been considered as the ". . . earliest special cooker . . . , of which the better known Nansen and Peary cookers are improvements"[160] It contained a pot resting over a spirit lamp, all of which was enclosed in a hood with a hole in the top. Over the hole was placed a pan of snow for melting (Figures 24 and 25a). Payer found this arrangement quite successful and recommended that such

> . . . cooking machines should be of different sizes, according to the number of men in the expedition. The largest of those used by us consumed ¾ lb. of spirits of wine to convert snow, with a thermometer from 130° to 22° below zero F., into three gallons of boiling water.[161]

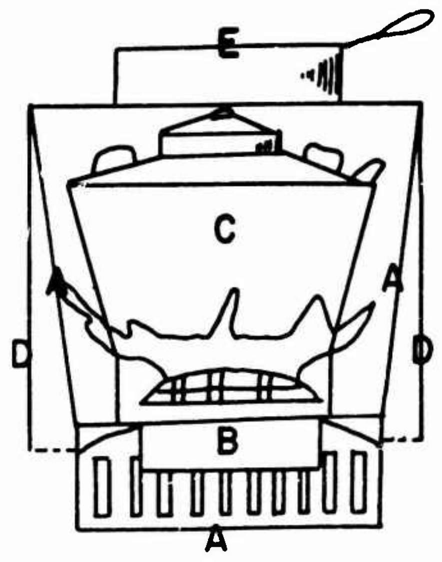
The next type of snow melter was developed by Greely, who increased the number of vessels (Figure 25b). The hot gases from the burning spirits rose through a hollow tube in the center of two tin vessels until they struck the bottom of the uppermost vessel, at which point smoke and some heat escaped. One advantage of Greely's cooker was that the pots, on being inverted, fit into each other for conservation of space.[162]

Nansen, in developing the "Nansen Cooker"[163] (Figure 25c), utilized Greely's cooker as a pattern. He writes that

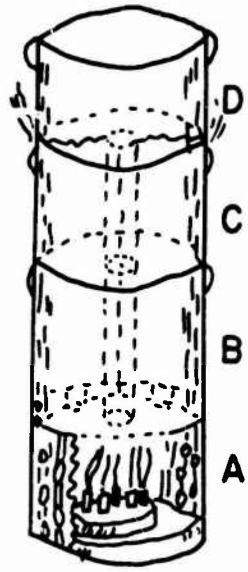
> The *cooking apparatus* we took with us had the advantage of utilizing to the utmost the fuel consumed. With it we were able, in a very short space of time, to cook food and simultaneously to melt an abundance of drinking water, so that both in the morning and in the evening we were

[155] *Ibid.*, p. 443.
[156] *Ibid.*, II, p. 172.
[157] *Ibid.*, p. 173.
[158] Nansen, *The first crossing of Greenland* (London: Green and Co., 1897). As quoted in Hostrup, Lyons & Associates, *op. cit.*, p. 130.
[159] The time element involved in snow melting is emphasized by W. Hobbs in *Peary* (New York: Macmillan Co., 1936), when he states that "On an expedition such as the North Pole one of Peary, the use of . . . an improved lamp may spell the margin between success and failure. . . ." p. 330.

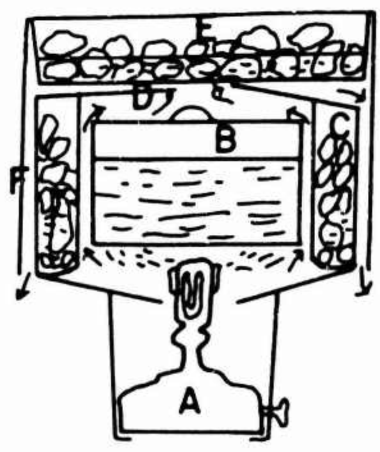
[160] Hobbs, "Cooking devices for arctic sledging use," *Encyclopedia Arctica, Misc.* (unpubl.), p. 1. Kane's cooking apparatus developed a decade earlier, should possibly be considered the earliest as it is similar except that it used an open pan for its fire.
[161] *Op. cit.*, p. 224. Although this heater was, relatively speaking, quite efficient, Payer writes in his journal that ". . . to make snow of such coldness boil quickly we should have had to place the kettle over Vesuvius itself in the height of an eruption." p. 255.
[162] Greely, *Three years of arctic service*, p. 163. One of these cookers, a two-man size weighing only sixteen ounces, was called by Greely's men the "Tramps' Companion."
[163] D. Mawson, *The home of the blizzard* (Philadelphia: J. B. Lippincott Co.), as quoted in Hostrup, Lyons & Associates, *op. cit.*, p. 132.



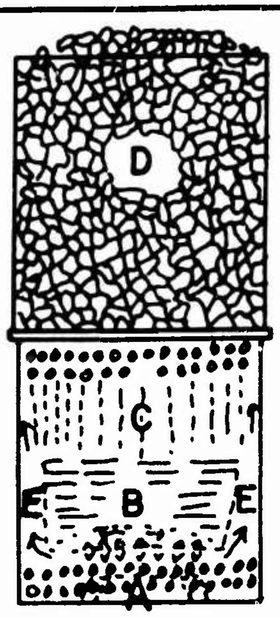
a. Payer's cooking apparatus. Payer, *op. cit.*, drawing on p. 224.
A — inner compartment
B — holder containing about a bottle of spirits
C — covered pan for cooking
D — outer case
E — pan filled with snow and fitted with a movable handle



b. Greely's field cooking apparatus. Greely *op. cit.*, drawing on p. 163.
A — sheet-iron cylinder with perforations
B — tin fireproof vessel with cylinder in center
C — tin fireproof vessel with cylinder in center
D — tin bucket
E — alcohol lamp



c. Nansen's cooking apparatus. Nansen, *Farthest north*, I, drawing on p. 470
A — primus
B — boiler
C — ring-shaped vessel for melting snow
D — lid over C with hole in middle
F — flat pan for melting snow
I — cap keeping hot air in cooking apparatus



d. Peary's alcohol cooker. Hobbs, *Peary*, drawing on p. 330.
A — alcohol lamp
B — boiling water
C — hot air and steam dripping thaw water
D — crushed ice

Figure 25. Snow and ice melters.

> able to drink as much as we wished, and even a surplus remained. The apparatus consisted of two boilers and a vessel for melting snow or ice . . .[164]

Peary, during the many years he spent in the Arctic, devised a cooker which he used on the expedition during which he reached the North Pole. Peary wrote that this

> . . . new alcohol-stove . . . worked splendidly, enabling us to melt ice and make tea in ten minutes, a process which had on previous trips, with the old type stoves taken a full hour.[165]

Hobbs, in describing this heater (Figure 25d), points out that

> All hot air from the burner passes upward outside the walls of the kettle through the row of holes near its top. Now mixed with steam from the boiling water in the kettle it passes up through the gauze bottom of the ice container through the interstices of the crushed ice mass. The thaw-water which results drips down into the kettle.[166]

Despite the added efficiency of snow melters, it was still of importance to be able to find the best snow for melting, if snow and not ice was to be used. Nansen, in crossing Greenland, assigned one of his Lapp helpers to that task. The importance of such a job is somewhat more implied than stated in the following comment:

> Ravana's evening task—and, I really think, the only regular work he had besides hauling during the whole journey—was to fill the cooking-vessels with snow. As an old Lapp who every winter used snow for his cooking-pot instead of water, he knew well what was the best kind for melting. So, as soon as we stopped, he would steal silently off with the cooker, dig himself a hole down to the old coarse snow, which melts into far more water than the newer, bring his pot back to the tent, and then, if it were already up, crawl in and sit with his legs crossed under him, not to move till supper was ready . . .[167]

Only a part of these special cookers has found general acceptance, that part being the Primus.[168] The Primus was quite soon adopted by the Eskimos and is used extensively by them today.

Even with the best of equipment, the melting of snow or ice takes time. Many of the explorers, as the Eskimos before them, tried various methods of carrying water or of preparing it on the march.

One technique, tried with some success, was to fill flasks (in more recent times, thermos bottles) with water prior to starting on the day's trek. These "field-bottles" were usually carried next to the body, though sometimes they were buried under as much baggage as possible on the sled, just as among the Eskimos.[169]

The explorers also carried flasks next to their bodies while marching and many tried to keep the part of the body where the flask was located turned into the sun as much as possible.[170] This method of water supply was not very satisfactory from the standpoint of either converting snow into water or of maintaining water in its liquid state. Koldewey found that ". . . often after many hours only a few spare spoonfuls (and sometimes nothing) could be obtained . . ."[171] from snow and Markham writes that " . . it was quite impossible to prevent the water in the bottles from being converted into ice, in spite of the tin water bottles being kept inside the waistband of the trousers."[172]

Only one instance of preparing water on the march in pre-motorized exploration was encountered in the literature. Payer wrote that

> Thirst compelled us frequently to halt in order to liquify snow; sometimes we melted it as we marched along, and our sledge with smoke curling up from the cooking-machine then resembled a small steamer.[173]

Today's Occupants

The Eskimos and explorers were satisfied with a water supply which often was scant and of poor quality; the Eskimos because of cultural heritage, the explorers because of a will to sacrifice. These two groups were also willing to procure water on an individual basis. With the development of permanent settlements and with the increasing im-

[164] *Farthest north* (London: George Newnes, Ltd., 1898), I, p. 470.

[165] *Secrets of polar travel* (New York: The Century Co., 1917), p. 263.

[166] *[illegible]ars*, p. 330. Hobbs also states that "Commander MacMillan later used this lamp . . . [and] With some modification . . . had it patented." footnote 11, p. 330.

[167] Reynolds, *op. cit.*, p. 61.

[168] Theories on sledging changed and all of the above heaters became obsolete. Although some of them were efficient ice and snow melters, they were too efficient in the sense that no warmth could be obtained from them, socks could not be dried. Later explorers believed that added warmth was of more value than the weight saved through the use of an "over efficient" heater.

[169] *Supra*, p. 108. Birket-Smith was written that ". . . when boiling water is poured into a thermos flask, which is thereafter packed into a caribou-skin bag, it can remain warm half a day on the sledge, even if the mercury in the thermometer freezes." "The Caribou Eskimos, . . . I, Descriptive part," p. 178.

[170] Koldewey, *op. cit.*, p. 420.

[171] *Idem.*

[172] A. Markham, "on sledge traveling," *Proceedings of the Royal Geographical Society*, XXI, No. 2 (1876), p. 114.

[173] *Op. cit.*, p. 306.

portance of the Arctic from the military standpoint, new attitudes are beginning to prevail. These new attitudes have led to attempts to increase quantity, improve quality, develop a year-round supply, and to change the supply from individual to group procurement.

Despite such a trend, many of the settlements of the North and nearly all of those north of the tree line still have relatively primitive water-supply systems. Changes have been instigated so recently that most are still in the experimental stage. In general, there appears to be a tendency to adapt techniques used in cities in lower latitudes where special precautions have been made for cold winters.

Recent developments have affected the source used, methods of processing, transportation, and storage of water in the Arctic. The ways in which such developments have proceeded are discussed under the following headings: a. Practices followed in contemporary arctic settlements, b. The Distant Early Warning Line, its water problems and solutions, and c. Field techniques developed by and for the military. These groups are ranked in order of decreasing permanency of situation, a condition which has an important bearing on the source and the technique used.

Practices Followed in Contemporary Arctic Settlements. In the North today, the improvement in water supply systems and techniques has been greater to the south of the tree line than north thereof. The solutions some cities, such as Fairbanks, Alaska, have made to their water problems are probably indicative of the solutions, with some exceptions, that will be made in the future north of the tree line. For this reason, in the present discussion, many examples have been drawn from techniques in use outside the Arctic.

Sources Utilized. The most desirable source is one with adequate volume available throughout the year. For settlements of any size in the North, it is now considered that such a source is only to be found in subpermafrost aquifers. Thus it would be obtainable only with deep wells. Such wells are being used in several northern settlements, all of which, however, are outside the Arctic. Wells at Fairbanks, probably the best developed in the American Arctic, furnish an adequate supply from below and within the permafrost throughout the year. Many localities use well water during one season, but relatively few have wells that function throughout the year. The water system at Dawson City, for example, utilizes deep well water during the spring when the Klondike River is muddy.[174] At Fairbanks, nearly the entire populace depends on well water furnished by the city, although there are some private wells in the city. At Mayo Landing, on the other hand, such wells as there are, are private. These wells are relatively few in number; most people depend on the river for water.

Although wells are proving functional in the Subarctic, none has been more than seasonally successful north of the tree line. Wells which have been drilled to subpermafrost depths have produced only salt water. There are some shallow wells in the Arctic, such as one at the Civil Aeronautics Station at Kotzebue. This well, which is thirty-five feet deep, furnishes water from April to September, being frozen the rest of the year.[175]

Rivers or lakes, although the second most desired of sources, are the most commonly used of the year-round sources. Most settlements in the Arctic are located close to rivers or lakes, many of which do not freeze to the bottom in the cold season. The Klondike River, except when muddy in spring, furnishes water for Dawson City. Quality is a factor frequently influencing the water source used, as is indicated by the supply system at Aklavik (old site). Lake water is piped to the townsite because Mackenzie River water is considered unclean. At Fort Simpson, where river water is used for washing but not for drinking, more than one source is used.

Another source which may give year-round service is the relatively rare winter-flowing spring. The city of Nome is so favored. The inhabitants haul their water from springs which are located about one-half mile from the city limits.

Winter supply, and in some instances summer supply, in most arctic and some subarctic settlements, remains ice and even snow. At Kotzebue "During the long winter 90 per cent of the water used for all purposes is from melted snow and ice. All drinking water is obtained in this manner."[176] At Churchill most families store ice for melting throughout the year. At Fort Simpson, while washing water is taken from the river, drinking water is obtained from ice that has been stored in the winter for melting in the summer.

[174] Ridge, *op. cit.*, p. 274
[175] Hostrup, Lyons & Associates, *op. cit.*, p. 26.
[176] *Idem*

Figure 26. Water supply for a Barrow restaurant. The ice is to be melted for cooking and drinking water, the snow for washing dishes.

There is also selectivity between snow and ice dependent on its use. At Point Barrow, in April, 1957, a local restaurant was using both snow and ice for water (Figure 26). Melted snow was used for washing dishes while the melted ice served as drinking and cooking water. The Arctic Research Laboratory, located a few miles from the village of Barrow, Alaska, hauls water from a lake to storage tanks throughout the winter.

The Weather Bureau stations which have been established in the Arctic utilize a variety of sources of water. The floating stations are normally able to obtain a sufficient quantity of snow from the top of the sea ice to provide all the water needed. Freshened sea ice, although it has found no general acceptance in the Arctic, is used when the need arises at several of the weather stations,

> . . . usually at an intermediate season when there is insufficient snow or other sources of fresh water. For example, between September 15 and November 15 new sea ice is frequently too thin to drive vehicles or tractors out to places where icebergs are available. At this time there is usually insufficient snow accumulated for making water and the next best source is freshened old sea ice which is cast upon the shore or stranded near the shore by winds and pressure.[177]

However, such sources are used rarely, for all of the weather stations in the Canadian Archipelago have lake sources available.

The source or sources used by different groups frequently differ apparently because of cultural heritage. At Fort Simpson "The native inhabitants use river water for all purposes."[178] The white residents, on the other hand, store ice for drinking and cooking purposes and use well or river water for all other purposes.

Processing, Distribution, and Storage. River, lake and well water are generally considered ready for use, although they may be processed first at some settlements.[179] Snow and ice, before being used, have to be cut, transported, and converted from a solid to a liquid. The techniques used by the Eskimos and explorers were developed for relatively small-scale production. Nevertheless, many of the same techniques are still used.

Possibly the most widely used method of melting snow and ice is with space heat where a container is kept full of water with the snow or ice being added as the water is used. This method is used in most private homes in the Arctic. Schools, hospitals, and government buildings often have special melting tanks equipped with steam coils.[180] Methods used often vary seasonally. At Tuktuyektok, during late winter and early spring, barrels are filled with ice so that it can melt in the heat of the sun. This method is used because during the "bad spring season one can't get around much" and, therefore, acquiring fresh water from ponds is difficult.

According to Hostrup, *et. al.*, ". . . conveyance and distribution of water from the source to the points of use probably presents (sic) more mechanical difficulties than other phases of water works engineering in the arctic"[181] Water transportation at many of the arctic settlements today is still on an individual basis, either in hauling water from a river or lake or in cutting and storing ice for later melting. Even when water is piped to the town, taps may be placed on the streets. Thus, people must have some storage facilities in-

[177] Glenn Dyer, personnel communication. Letter dated 14 July 1958. R. Rae in "The problem of establishing and maintaining weather stations in the Arctic," *Proceedings of the Toronto Meteorological Conference, September 9-15, 1953* (1954), points out that icebergs are preferred over sea ice, and that at some stations they ". . . provide one of the main sources of fresh water." p. 88. He also writes that in the winter of 1952-3 ". . . the Eureka station was poorly off for fresh water as no icebergs were located near enough to the station to be used. To avoid a similar situation, the U. S. Coast Guard icebreaker *Westwind*. . . attempted to tow an iceberg and leave it aground on a sandbar near the station." p. 89.

[178] Ridge, *op. cit.*, p. 448.

[179] A study of great importance in the Arctic that has had very little consideration has to do with water treatment. Alter, *op. cit.*, writes that "Coagulation, settling, filtration and other treatment processes such as aeration and disinfection are all affected by temperature." p. 225. Also, biological and chemical reactions are retarded by low temperatures and thus may prolong the life of pathogenic bacteria. This fact, coupled with the practice of carelessly disposing of sewage and other wastes, increases possibilities of water contamination.

[180] Dyer, *loc. cit.* writes that the weather stations rendering snow and ice into water ordinarily use ". . . a large metal tank into which the ice or snow is entered by shovels or hand. This tank is usually connected to a heating coil in a stove which provides circulation so that the ice and snow can be melted by convection and or merely being in the proximity of heat, although the latter is a slow and inefficient method. In all instances we have a receiving tank connected with circulating hot water in a stove or in some cases a tank is heated by a lengthy exhaust pipe for generating plants, which is a very efficient system."

[181] *Op. cit.* p. 154.

side their homes. Delivery of water on a commercial basis usually takes one of two forms, pipe line or hauling, which may alternate seasonally. Most delivery is made by truck or sledge and barrel. For example, at Hay River water is supplied under franchise by a trucker. This water is drawn from the river and

> . . . sold within the settlement at a dollar a barrel, or one-and-one-half cents per gallon. The tank truck has a capacity of 1,000 gallons and is emptied three times a day.[182]

The same price was received per barrel for water hauled at Tuktuyaktok in the summer of 1956.[183] At Tuktuyaktok water is hauled from a fresh-water lake in the delta by boat.

Hauling of water is often somewhat easier in winter than in summer because of the ease with which one can move over the surface and because leakproof containers are not needed. Snow and ice can be hauled on a sled (Figure 27) or on the back of a truck to a storage pile for later use (Figure 28). At Barrow, Alaska, the Native Service Store uses motorized methods of hauling ice during the fall months when the lakes have a cover of ice ten to twelve inches thick. This ice is stored and later sold to native families.[184] Many of the families have their own cellar in which they attempt to store

> . . . sufficient ice to make drinking water, as well as some water for washing and other purposes for several months to come. The amount of ice packed actually depends on the size of the local ice cellar. If a house-holder has a sufficiently large cellar, he may attempt to store a considerable surplus of ice blocks; these, too, have an economic value and may, if there are extra on hand, be sold.[185]

Pipe-line distribution is found in a variety of forms in the different arctic settlements, dependent upon local physical and economic conditions. Pipe lines may be placed aboveground or buried in it; they may be insulated and/or heated and used throughout the year; or they may be unprotected and used only during the warm season.

Aboveground unprotected systems are operated at many settlements during summer. At the old townsite of Yellowknife, where bedrock is found

Figure 27. Family water supply, Barrow, Alaska.

at the surface, water lines can not be buried. Thus, despite the fact that water is piped throughout the year to the dwellings in the new townsite, it is furnished only during the summer to residents of the old townsite. In winter, people in the old townsite buy water from a trucker.

Other settlements insure running water throughout the year by using protected distribution lines. Methods of keeping the water from freezing in transit are quite varied. At Churchill, Manitoba, although most families store ice, the government has established a water supply line to a few of its facilities. This aboveground line, extending eight miles from its source, is insulated with moss. During winter, water from the lake, before being piped to Churchill, is heated to 70° F. Nevertheless, it arrives with a temperature only slightly above freezing.[186] Many types of insulation besides moss are used, including clay and peat[187] and wood shavings.[188]

Other distribution systems have been developed for year-round use by placing lines in heated boxes or conduits, known in the Arctic as "utilidors." Utilidors may vary from simple conduits to elaborate concrete tunnels such as those at Ladd Air Force Base, Alaska, which are large enough to walk through. Varying methods of heating utilidors are used, including: (1) electricity, (2) circulation of warm fluids, (3) circulation of warm air, and (4) enclosure of steam lines in the utilidor. The Imperial Oil Company at Norman Wells used the last method, when it included its water and sewage lines in the same conduit with its steam lines. Steam lines keep the temperature in

[182] Ridge, *op. cit.*, p. 387.
[183] The 1956 Tuktuyaktok water hauler quit his job because, at one dollar per barrel, he was not making enough money.
[184] W. Boyd and J. Boyd, *op. cit.*, p. 891.
[185] R. Spencer, *The north Alaskan Eskimo* (Washington: U. S. Bureau of American Ethnology, 1959), Bulletin 171, p. 369.

[186] W. Hyland and M. Mellish, "Steam heated conduits—utilidors—protect service pipes from freezing," Civil Engineering, XIX (1949), p. 27.
[187] Hestrup, Lyons & Associates, *op. cit.*, p. 165.
[188] *Ibid.*, p. 29.

the conduit sufficiently high to prevent freezing.[189]

Many settlements in the North have underground systems which deliver water throughout the year. These lines are buried at various depths depending partly upon permafrost and active-layer conditions. While lines aboveground are subject to the extreme fluctuations of temperature of the air, those buried in the active layer have variations of a lesser magnitude and those buried in the permafrost have temperatures which are fairly constant at only a few degrees below freezing. The burial of pipes at a depth just beneath the seasonal frost line is the technique used in Russia, for alleged economic reasons.[190]

The usual method used in these subsurface lines to prevent freezing is continuous flow. Continuous flow, if water is plentiful, may be maintained by keeping taps open, or it may be maintained through a recirculation system. The water may be heated at the source and/or its velocity through the system may be increased as air temperature decreases. The system at Fairbanks incorporates all of these practices. Its system has lines buried six feet below the surface through which it continuously circulates preheated water. During colder weather the velocity of the water is increased to the point where, during the circuit of the water, heat dissipation is not great enough to allow freezing.[191]

Storage of water in arctic settlements is on a family basis except for those few instances where water is piped into the houses. At Frobisher Bay water is hauled to the various houses twice a week and placed in barrels. The Eskimo families have barrels with a capacity of forty-five gallons, whereas the white families have barrels that will hold 145 gallons. Ice storage is also common and can be in cellars, on the surface of the ground, or on special platforms (Figure 28).

Figure 28. Ice storage for water supply at nurse's home, Tuktuyaktok, Canada.

From the above discussion, it may be concluded that the variables affecting the sources and techniques utilized in present arctic settlements include: geographic location, permafrost conditions, economic status of individuals and settlements, proportion of natives and non-natives, and uses made of water. At present, knowledge of the distribution of these variables is so limited, regionalization is not possible.

The Distant Early Warning Line, Its Water Problems and Solutions. Although, as maintained by Alter,[192] the location of communities in low-temperature areas may be governed by water supply, during the most recent development in the American Arctic, water supply was all but ignored in choosing suitable sites. Governing the location of each of the radar sites of the DEW Line were factors which often were unfavorable to the best water supply. A site had to be located so that no terrain feature would interfere with the radar equipment. Thus, valley locations, where the best possibilities for water are most often found in the Arctic, could not be utilized as sites. Also, the fact that the sites had to be equal distances apart did not favor water development.

All sites had to be supplied with water from surface sources, either liquid or solid. Personnel at those stations located near deep lakes were able to keep a water hole open throughout the winter and therefore used only one source. The personnel at the other stations, although able to use lake water during the summer, had to resort to the use of ice during the cold season. At some stations snow was also used as a source of water.

The DEW Line development is of interest to students of arctic water supply from two standpoints. There was the problem of supplying relatively large construction crews with water for a year or two and the additional problem of devel-

[189] Hyland and Mellish, as quoted in Hostrup, Lyons & Associates, *op. cit.*, state that "The utilidor system is a more practical installation than the conventional (buried) type of utilities system for a community such as a permanent arctic military base where all utilities, including central heat, are supplied by a single agency, and for arctic municipalities financially able to provide a central heating plant. The conventional system is the more suitable type of installation for small communities financially unable to provide a central steam plant. However, this type of system is more vulnerable to operational difficulties." p. 171.

[190] Hyland and Mellish, "Steam heated conduits . . . ." p. 28.

[191] "Arctic water supply: it must circulate or freeze," *Engineering News Record*, CLII (1954), p. 30.

[192] *Op. cit.*, p. 219.

Figure 29. Pumphouse and Eskimo water-truck driver at lake source, Frobisher Bay, Canada.

oping a water supply sueh that the personnel operating the radar stations would have to spend a minimum amount of time seeuring it. The quantity of water needed was mueh greater for the construetion phase than for the operational. These relatively great demands were met in a variety of ways, many of whieh were on-the-spot innovations by DEW Line eonstruetion personnel.

In the construction phase of DEW Line development, time was the important factor; expense, though important, seemed secondary. Water was often obtained on a very primitive basis beeause of laek of knowledge of sources and of processing teehniques as well as laek of time to develop adequate procedures. Also, expenditures in developing a supply sufficient for a large camp would not have been warranted due to the short-term nature of the great demand.

A consideration of the water supply problems and solutions encountered during the construetion of the DEW Line should serve to indieate some of the problems and solutions that any temporarily established group could expect in the Aretie. One difference will probably be that, in the latter situation, a source of water would be a determining factor in the choice of a site.

After the preeise locations of the sites had been determined and the construction crews moved in, water supply became more than an individual problem. Water details were established to furnish water in both summer and winter. It was a common practice along the DEW Line to use Eskimos on water details. Ponds, lakes, and rivers are frequent enough along the DEW Line so that the personnel at all sites were able to use them as a source of water during the summer months although often only with lengthy hauls.

Hauling of fresh water during winter was the preferred method. This praetiee neeessitated the maintenance of water holes through the ice of lakes whieh did not freeze to the bottom. If such a lake existed in the vieinity of the DEW Line site, the water detail would build a "shaek" on the iee over the deepest part of the lake after the iee had beeome suffieiently thiek to support the strueture. This shack became a pumphouse and was equipped with a stove and pump. The stove was neeessary to keep the hole and the pump from freezing (Figure 29).[193]

The manner of hauling water varied greatly. If the lake was not too far from the eamp and if the road was adequate, an unheated truek was used (Figure 30). Where, however, these eonditions did not prevail, other means of earriage had to be used. Usually these involved a caterpillar traetor and a wanigan. In some instanees the wanigan was a large tank (usually 1,000 gallons) enclosed in a small frame building whieh was heated to keep the water from freezing on the haul from the lake to the point of use (Figure 31).

Figure 30. Unheated water truck, Frobisher Air Base.

[193] Dyer, *loc. cit.*, writes that during the winter, weather stations able to secure water from beneath the ice in most instances keep the hole ". . . open by one electric lamp bulb located under an insulated cover."

Another technique which is apparently efficient was used at the weather station at Resolute. R. W. Rae in "Joint arctic weather project," *Arctic*, IV, No. 1 (1951), describes it as follows: "In the fall when the ice was between one and two feet thick, a 9-foot length of 3-inch pipe was frozen into the ice with its top just above the surface. Then a 3-foot extension was secured to the top. This 3-foot length provided sufficient pressure head that when aviation gasoline was poured in, the gasoline forced the water completely out of the pipe. Instead of a pipe full of water, there was now a pipe full of gasoline embedded in the ice. When is was necessary to haul water, the extension was unscrewed and the water pressure from below forced the gasoline out of the pipe, which was then linked to the intake hose and pump." p. 23.

C. Simpson in *North ice* (London: Hodder and Stroughton, 1957) writes that his group found the best method to get water from a lake ". . . was to hack a basin in the ice about 3 feet deep and then, using a 1½-inch diameter ice drill, bore downwards from the bottom of the basin to the water below . . . Water then gushed up into the basin, and [they] could fill [their] buckets . . . When the drums were full [they] plugged the hole with cotton waste and bailed the basin dry ready for a fresh drilling." p. 358.

Figure 31. Space-heated water wanigan, Baffin Island. The picture shows water being pumped into the laundry at one of the DEW line sites.

Figure 33. Eskimo laborers sawing lake ice and scraping off the "ice dust."

Occasionally unheated water tanks were used, often at a great loss in pay load. At one site one such tank was two-thirds filled with ice (Figure 32).

The other major technique used in securing a winter water supply at the DEW Line sites was by gathering and melting ice. One advantage of this technique over the hauling of fresh water was that the distance of haul generally needed not be as great. At all of the sites without deep lakes ice was the only source other than snow. However, the necessary energy to gather and melt ice more than offset that required to keep a hole open through the ice of a deep lake and to haul the water in a liquid state.

The method of processing ice along the DEW Line assumed mass production proportions. The first step, after water could no longer be obtained from under the ice,[194] was to clear the snow from the ice. This was followed by cutting the ice into blocks with a power saw,[195] after which the "ice dust" was scraped away (Figure 33). Men with jack-hammers would further loosen the blocks (Figure 34) which were then scooped onto a sled (Figures 35 and 36). The sled was hauled to the boiler house where the ice was melted for distribution as water by truck around the camp (Figure 37).

Water supply at most construction camps was generally on a day-to-day basis. At times keeping an adequate supply became quite difficult and even was restored to individual procurement. Such conditions occurred most often as the result of storms which restricted travel between the camp and the water site and/or when a complete breakdown of transportation occurred. Even as

Figure 32. Unheated water wanigan being emptied into module. This wanigan tank is two-thirds filled with ice.

Figure 34. Loosening ice blocks with jackhammers.

[194] The time when water from under the ice can no longer be used is frequently determined by the increasing turbidity as the ice layer thickens. *Supra* p. 110.

[195] The Bureau of Yards and Docks, as reported in "Improved ice harvesting," *Military Engineer* XLI (1949), in the late 1940's experimented with ice cutting equipment and developed a light-weight timber tractor saw which was capable, with a six-man crew, of cutting and storing forty tons of ice in eight hours. During the experimentation, they found that a thick blade was needed to prevent the possibility of the ice refreezing before removal of the blade (p. 291). This quantity contrasts greatly with the thirty blocks of ice that de Poncins and Gibson cut in a day with an eight-foot crocodile-toothed saw. G. de Poncins, *Kabloona* (New York: Reynal and Hitchcock, Inc., 1941), p. 49.

Figure 35. Scooping up ice blocks for loading on sled.

Figure 37. The Fox Water Works. Behind the water truck is the building in which the ice is melted. The truck distributes the water around camp.

late as April, 1957, when the construction phase of the DEW Line was coming to a close, water procurement was at times critical. At one site all of the tractors were out of commission so that no method of hauling the water wanigan from the lake was available. The road to the lake, four miles down into a valley, was in such condition at the time that a 4 by 4 truck could use it. Four empty gasoline drums were loaded on the truck, taken to the lake, and filled. After returning to the site, the first step was to replenish the kitchen supply which had been completely exhausted (Figure 38).[196] Then, the rest of the water was transferred by bucket to a pumping system located in the washroom (Figure 40). From the washroom it was pumped into a storage tank which was enclosed in a heated building with insulated pipes leading to the kitchen and back to the washroom (Figure 41).

At the construction camps the cooking was done on a messhall basis, and it was the responsibility of the water detail to supply water for this purpose. However, all of the messhalls had arrangements for melting snow and ice and for keeping water from freezing. Generally these melters were made by metal workers on the spot without the aid of a formal pattern (Figures 42 and 43).

All of the dwelling tents were heated and they invariably included a bucket as an essential item of furniture. The bucket was kept near or on the stove. The water for it was furnished either by the camp water detail (Figure 44) or by the men themselves. Occasionally ice was placed near a central position in the camp and the men could melt this in their tents (Figure 45). In other instances, however, men would use the most convenient source (Figure 46). In such instances quality was of secondary importance.

The second phase of the water-supply problem faced by the DEW Line contractors was the establishment of an adequate supply for the operation of the sites after the construction crews had completed their jobs. In order to accomplish this

Figure 36. Dumping ice blocks onto sled.

Figure 38. Water being transferred from gasoline drums to the kitchen. The condensation of water vapor in the cold air is conspicuous. Compare with Figure 41.

[196] While waiting for water to be brought by the 4 by 4 truck, one of the cooks got a bucket of snow from back of the kitchen "in order to wash dishes." (Figure 41).

Figure 39. A cook at one of the DEW Line construction camps getting two buckets of snow in order to wash dishes.

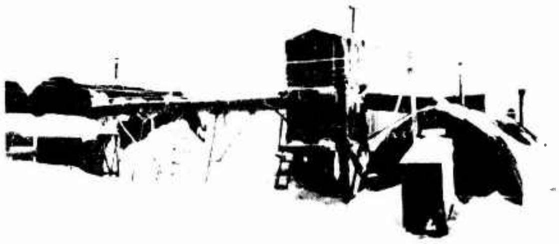


Figure 41. Water-supply arrangement at a DEW Line site. The heated storage tank is in the middle with covered lines leading to the messhall on the left and the washroom on the right.

task the contractor of the DEW Line requested that the firm of Seeyle Stevenson Value & Knecht, consulting engineers, provide information about water sources along the DEW Line and that they recommend ". . . methods of development of water sources, and conveying the water to the building area."[197] Their report, submitted on February 10, 1956, included information which reflects the nature of the water problems to be found along the northern coast of Canada and Alaska.

Personnel of Seeyle *et al.*, visited, in the winter of 1955–56, eight sites in the western sector, eleven in the central sector, and six in the eastern sector, nearly one-half of the total number of sites. Of the twenty-five sites actually visited, the investigators concluded that at twenty-three adequate supplies of water for all purposes were available.

The somewhat arbitrary criteria established to determine adequacy of supply (that is, enough to furnish a minimum of thirty gallons of water per person per day) were:

> 1. A lake, creek, or river of sufficient volume of at least one years' storage should be available.
> 2. The area of the watershed should be of sufficient size to replenish the supply each year. Since very little is known about the snowfall and snow melt, at the various installations, it was decided for the sake of being conservative, to use a total yearly collected runoff of 1 inch per year for the watershed.[198]

As ground water was not considered, the engineers were concerned only with locating a lake or river of adequate quantity and quality. Of the twenty-five sites visited, in only two instances were rivers suggested as the source. At the rest of the stations the use of ponds or lakes was advised, and in one instance it was recommended that a lake be created by damming. Thus—despite the often adverse location of a station in relation to a water supply—it was shown, that with modern

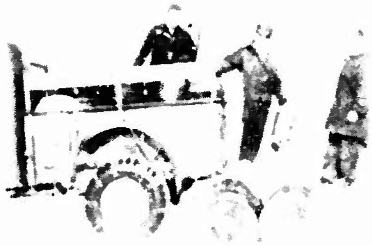


Figure 40. Transferring water to washhouse, where it is pumped to a storage tank.

Figure 42. Water barrels in a kitchen at a DEW Line site.

[197] Seeyle Stevenson Value & Knecht, *Report on water supply for the DEW Line* (New York, 1956), Letter of Transmittal.

[198] *Ibid.*, p. 3.

Figure 43. A snow-and-ice melter made from oil drums.

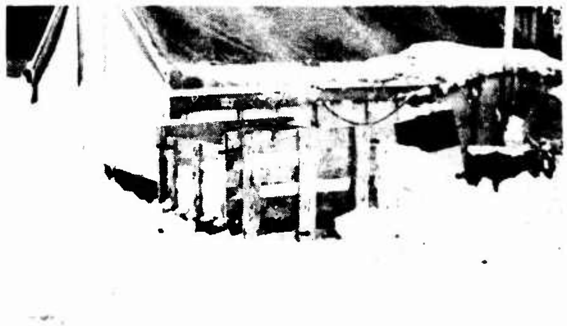


Figure 45. Ice storage for use of tent personnel.

types of transportation, lakes are within reach and can be utilized at nearly any point in the coastal section of the American Arctic.

Another method of moving water recommended by the investigators was by pipe line. They suggested the use of either heated pipe lines without supplemental storage. The heated lines were recommended where a source was deep enough so that it would maintain sufficient quantity of water under the ice throughout the cold season, providing it was within 5,000 feet of the site.[199] Such conditions prevailed at eleven of the twenty-five sites. The average depth of water at these eleven sites was seventeen feet, although six of them had depths of eleven feet or less. The average distance from the lake to the station was 3,000 feet.[200]

At those sites where lakes are less than eight feet deep or where the distance is too great, it was recommended that supplemental storage be used and that either an unheated pipe line be constructed from the source to the storage tank or that water be hauled. The unheated pipe line was recommended for ten of the twenty-five stations, only two of which had lakes over eight feet deep. The average distance of these ten lakes from the sites they serviced was 5,000 feet, with five being 3,600 feet or less.[201] At the remaining stations hauling was recommended because of the great distance (one station's source was fifteen miles distant) or because it was necessary to use more than one source to insure an adequate supply. At one site there was a combination of these two conditions. The summer source was a lake three and one-half feet deep which, however, had a large volume. It was located eight-tenths of a mile from the site and had potable, though amber-colored, water. A lake with clear water, located some five miles from the station, served as the winter source. This desirable lake was not accessible during the summer because of the condition

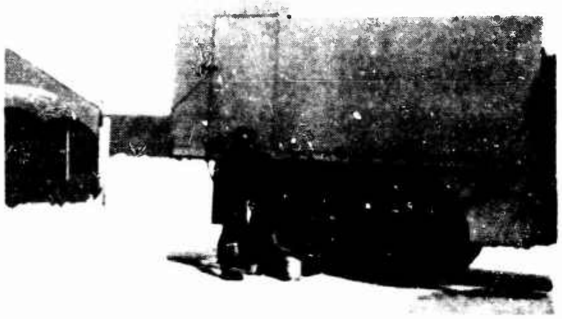


Figure 44. Filling bucket from heated truck for tent use.

Figure 46. Getting snow for a morning cup of coffee.

[199] *Ibid.* p. 4. The depth chosen was eight feet. A precedent had been established for this method in the development of the Pine Tree Radar Line. There, according to Staunton and Rosanoff in "Water for our far north outposts," *Engineering News-Record*, CLX (1958), water was transported in a heated pipe line from a heated pumphouse to enclosed storage tanks. The heated " . . . pumphouse is constructed either on top of a crib in the lake or on shore. If the latter, a tunnel is formed leading to a well under the pumphouse." p. 40.

[200] *Ibid.*, p. 4 ff.

[201] *Idem.*

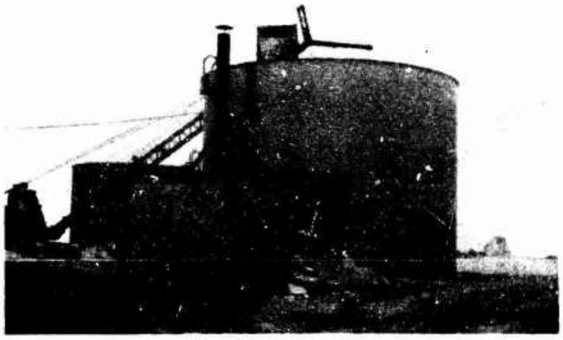


Figure 47. An experimental heated storage tank with 60,000 gallon capacity at a DEW Line site.

Figure 48. Ice crusher and ice elevator attached on one end of a DEW Line module.

of the tundra. Under a similar situation at another site it was reported that

> Summer hauling will be impossible unless an access road, prohibitive in cost, is constructed. It is evident that special provisions will be required at this location to haul all water in a wanigan after the first solid freeze and store a year's requirement at the site[202]

Because of such storage needs, various types of fluid and solid storage were tried. Just as a liquid source is preferred over a solid source, liquid storage is preferred to solid storage. Although liquid storage is easy to utilize it is, nonetheless, expensive to establish and to maintain, for it needs a continuous heat source throughout the winter. Bulk liquid storage was considered advisable only for large installations where supplemental storage was needed. One system field-tested by the DEW Line contractors consisted of a 60,000 gallon heated storage tank, a complete water purifying unit, and an ice crusher (Figure 47). Such a system was capable of producing water in winter by melting ice within its storage tank in case the demand was sufficiently great or in case liquid sources were insufficient during summer or autumn.

Although water in the liquid form is preferred, it was realized when the DEW Line was first planned that many of the stations would have to utilize ice during the winter months. As a result, all of the stations were equipped with a special unit, attached on the end of the modules, for converting ice into water (Figure 48). This unit has an elevator which lifts the ice from a crusher to the top of the building and dumps it into a melting tank. The quantity produced depends mainly on the melting rate inside the module. However, rate of use and storage capacity are also important factors. The storage of ice for use in the crusher-melter unit is solved by piling ice blocks near the modular building train (Figure 49). At some of the sites, during the construction phase, water was produced by these units to supplement that of the construction camp. More often, however, once the units began operating, it was found that the water they could produce was insufficient for the demand. The demand was far greater during the transition stage than it became later on under pure operation conditions. The ice crushers and melting equipment have been utilized extensively at all sites since the DEW Line became operational.[203]

The original investigating team visited only a portion of the auxiliary and intermediate sites. However, their report contains some information about the unvisited sites based on interviews. They concluded that water requirements at these

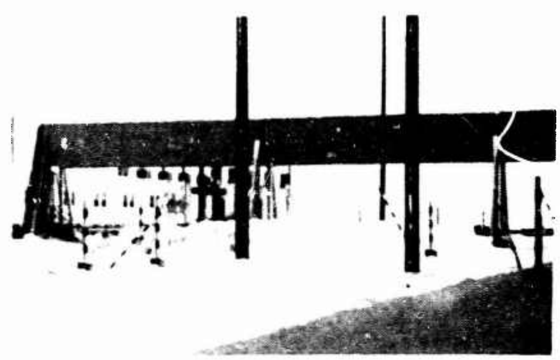


Figure 49. Storage of ice for crushing and melting in the adjacent building.

[202] *Ibid.*, p. D-?

[203] R. Crazen, personal communication.

Figure 50. Sled load of snow to be melted for water supply. The source area is approximately two miles in the background.

Figure 52. Filling plastic bags with snow water.

sites could also be met without undue difficulty.[204] Of the thirty-two sites included in this section of their report, all but four are of the intermediate category. Intermediate sites are manned by a complement so small that the investigators concluded that a pipe line with or without supplemental storage would not be warranted. As a result, they recommended experimenting with a type of solid storage. They suggested that

> Plastic bags, each capable of holding about 50 pounds of water, should be furnished each station in the proper amount, to accommodate the supplemental storage requirements. The bags would be filled during the hauling season and stored adjacent to station under tarpaulins. As water is needed in the station, one man could bring as many 50 pound bags of ice as needed into the tank module to melt.[205]

In March, 1957, this procedure was being initiated at one of the stations with, however, some variations in the proposed techniques. Instead of filling the bags from a lake, they were being filled with melted snow. The snow was hauled by sled (Figure 50), from a source area approximately two miles distant, to the melting station. There it was melted and pumped into plastic bags where the water froze (Figures 51 and 52). These plastic bags, held in shape during freezing by cardboard containers in which they were also stored, were then hauled to a tent near the module for storage (Figure 53). At this site, this source was to be used in summer as well as winter. After experimenting in the field and after actual use of this technique, it was decided that the plastic-bag method of storage has too many faults to be practicable. These disadvantages include the great amount of labor needed to prepare the ice for storage, the fact that leakage and spillage damages storage boxes which tend to freeze to each other, the great amount of labor needed to transfer the stored bags to the melting module, and the slow rate at which such large blocks melt.[206]

Figure 51. Funnel leading to snow melter at DEW Line site.

Figure 53. Tent for ice storage showing plastic bag and cardboard container.

[204] Seelye Stevenson Value & Knecht, op. cit., p. D-2.
[205] *Idem.*

[206] Cruzen, loc. cit.

Not all plans for insuring adequate water for the operational stage of the DEW Line involved processing at the site. At one location in the central sector water was available to a limited extent in a shallow lake in relatively flat terrain. The suggestion was made that ". . . a snow fence be built to aid in replenishing the lake.[207]

Field Techniques Developed by and for the Military. Although a large group of men could get along on the water obtained by melting ice and snow on a special heater, they would have to spend a large part of each working day in this one operation. Another alternative would be to assign special details to gathering ice or snow and converting it into water, again with a loss of effective man power. To melt even the one or two gallons necessary for drinking and cooking requires lengthy stops and extra fuel. All of these factors lead to a corresponding loss of overall efficiency of the unit. According to Hostrup *et al.*, "Producing a sufficient and continuous supply of water for several hundred men in a permanent project has not been successful from a practical standpoint."[208]. The armed services have engaged in experiments and field trials to cope with this problem. A Department of the Army field manual states that

> . . . melting snow and ice . . . for all needs to large units is impractical. . . . The chief sources of water supply for large units in the order of their efficiency and economy are drawing water from under river or lake ice, melting ice, melting snow, and well drilling (semi-permanent and permanent camps.)[209]

As water from under river or lake ice is the desired source, the Army has developed methods of getting through the ice to the water below as well as methods for keeping the water hole open. The Army considers that hand tools are inefficient for cutting through more than two feet of ice. It has found, however, that ". . . air tools, steam jets, and shaped charges or other explosives prove most effective."[210] Explosives are ". . . best used on streams. If they are used on lakes, the water becomes turbid."[211]

In order to decrease the possibility of a water hole freezing, any one or a combination of the following practices may be used: (1) continuous pumping, (2) placement of protective structures over the ice holes, and (3) covering the hole with a snow block which in turn should be covered with loose snow to retard freezing.[212]

When water is not present under the ice, the next best source is the ice itself. For mass production the Army advises using

> . . . improvised steam generators to melt ice in place. . . . In melting ice with the improvised steam generator, a fire-fighting fog nozzle attached to the steam hose will melt a hole 12 inches in diameter and 3 feet deep in 5 minutes. A good method is to melt a dozen or more such holes close together, in a circle, and join them by melting the ice in between.[213]

Other experiments have been made in melting ice on a large scale with portable ice melters. During Army operations in the Arctic, ". . . two 50 gph and two 500 gph ice and snow melters, . . . mounted on skids with hardwood runners . . ."[214] were tried. Results from three experiments showed that the melters needed simplification, a conclusion that was also reached after tests of three other ice melters on the Greenland Ice Cap in 1954.[215].

Despite the fact that an adequate melting system has not been worked out,[216] it has been concluded that ". . . the real problem in ice melting for a water supply is the mechanics of procuring, hauling and placing the ice in the melter or of conveying the water from the ice melter . . ."[217] Various techniques for storage and transport have been postulated and tried. These vary from individual to group methods.

In recent years canteens have been field tested. During one test in the late 1940's, it was found

---

[207] Seevie Stevenson Value & Knecht, *op. cit.*, p. A 30-1.
[208] *Op. cit.*, p. 133.
[209] Department of the Army, "Administration in the Arctic," p. 38.
[210] *Idem.* This field manual also states that "The M2A3 charge, when placed directly on the ice, blows a hole through 63 inches of ice, 3 inches in diameter, with a surface crater about 3 feet in diameter and 14 inches deep. Three blocks of TNT detonated in the penetration hole increase the diameter to 8 inches." p. 39.
[211] *Ibid.*, p. 39.

[212] *Idem.*
[213] *Ibid.*, p. 38.
[214] Hostrup, Lyons & Associates, *op. cit.*, p. 133.
[215] R. Schmidt, *Report on Greenland operation, 1954* (Fort Belvoir, Virginia: U. S. Army Engineer Research and Development Laboratories, 1957), p. 16. Just the year before (1953) an Air Force sponsored expedition on the Greenland Ice Cap found that, for twenty men, "A large open kettle for melting snow on each stove assured a constant and plentiful supply of water . . ." J. Nelles, "Construction and maintenance of the Mint Julep station," *Project Mint Julep*, Pt. 1 (1955), p. 42.
[216] The Russians also have experienced difficulty with this problem as is indicated in the statement regarding their camp at the 1950-51 drifting station. "A snow melter to assure a supply of fresh water was also prepared on the spot from an iron drum. First it was placed outside, near the tent, and heated with a large aviation lamp (API). The gasoline was fed into the lamp. Water was supplied directly to the kitchen by a rubber hose insulated with reindeer fur and provided with a spigot like on a samovar. The API lamp, however, was not very useful for constant, prolonged usage . . . When winter came, new attempts were made to construct snow melters with different sources of heat, but no satisfactory solution to this problem was ever reached. Somov, *op. cit.*, I, sec. 1, p. 6.
[217] Hostrup, Lyons & Associates, *op. cit.*, p. 136.

that movement of canteens ". . . slowed down considerably the rate of freezing; and when they did freeze, thawing of the contents on the Coleman stoves was easy. At night canteens were kept warm inside the sleeping bags."[218] The United States Quartermaster Corps has experimented various methods for keeping water from freezing in canteens. They have ". . . conducted a comprehensive investigation of compounds to depress the freezing point of drinking water or to produce a semi-liquid mixture."[219] The compound added must be palatable and must cause no adverse physiological effects. Some of the compounds tested produce a mush formation which can be poured freely.[220]

Containers, such as five-gallon cans, are used for storage and distribution. Freezing, in these cans and in larger storage units, can be prevented by utilizing immersion-type heaters.[221] The Army recommends that, in transporting water from its source in five-gallon cans, the cans be filled only three-quarters full to allow agitation of the water in transit.[222] It was found that

> For small units of two to four men, the 5-gallon insulated food container is satisfactory. These can be filled each night with water from melted snow or ice, or from unit water dispensers. They hold enough water for the next day's needs for about four men. The insulation is sufficient to keep water from freezing for as long as 40 hours at an ambient temperature of —20° F, if the temperature of the water was at boiling point when the container was filled.[223]

Transportation by truck may depend upon the development of a road net which often is impractical. Movement by tractor or runner-equipped vehicles and sleds is feasible in most of the Arctic. This type of transport and storage requires heated water compartments—heated either by space heat or immersion heaters. The Army has found that, "Sled-mounted 250–300-gallon water tanks in which immersion-type heaters have been installed, have proven satisfactory."[224]

---

[218] Johnson and Kark, *op. cit.*, p. 26.
[219] *Prevention of freezing of water in canteens* (Lawrence, Mass.: Research and Development Branch, 1946), Rept. 4603, p. 5.
[220] *Ibid.*, p. 7.
[221] Immersion-type heaters were used on floating station Charlie in the Arctic Ocean during 1959 for melting snow and were satisfactory in supplying a camp of thirty men.

[222] U. S. Department of the Army, "Administration in the Arctic," p. 38.
[223] *Ibid.*, p. 40.
[224] *Idem.*

Food Supply in the Arctic

When the Greek "Parmenides of Elea (about 460 B.C.) divided the earth's sphere into five zones or belts, of which three were uninhabitable . . .",[1] he established a regional scheme which has plagued man to the present time. One of the three uninhabitable zones was that part of the spherical earth to the north of the Arctic Circle. Being an area "permanently covered" with snow and ice, it was "logical" to conclude that life could not exist there, neither man nor the plants and animals man depends on. The European, however, upon gradually entering this "uninhabitable" area, found not only forms of life that could be used as food by man, but man himself.[2] Yet, the idea of a northern limit of life persisted, even though its southern boundary was gradually pushed poleward.[3]

Explorers came to realize that life existed in the Arctic, but many then considered that it was either so sparse that it could not be utilized or else that it was only present during the warm season and therefore not available during the trying winter. Such ideas prevailed long after it was realized that Eskimos remain in the Arctic throughout the year and obtain sufficient food to subsist. Even today, living "off the land" is often considered something only an Eskimo can do. An analysis made by Howard of some 268 survival accounts in the Arctic during World War II pointed out the reluctance of non-natives to use available resources. Howard found that less than 10 per cent of the individuals involved tried to supplement their food supply from the area around them.[4] This failure undoubtedly accounted for the death of many who might otherwise have survived.

Snow and ice, although not indicative of lifelessness as formerly believed, nevertheless do have an important bearing on the geographic and temporal distribution of life forms in the Arctic. Caribou, for instance, could hardly move to and from the islands of the Canadian Archipelago without a seasonally frozen connection, or again, zones of rough sea ice are little frequented by seals. Knowledge of such snow-and-ice-affected distributional patterns is of critical importance to hunters. Snow and ice, frequently considered an economic hindrance, are often utilized to advantage in capturing game. The degree of such utilization, even by the Eskimos, varies greatly, ranging from extensive usage by the Netsilik to the opposite extreme by the south Greenland natives who, like most non-Eskimos, consider snow and ice to be hindrances in hunting.

[1] Nansen, *In northern mists*, (New York: Frederick A. Stokes Company, 1911), I, p. 12.

[2] John Davis was one of the first to make this observation when he wrote ". . . it is most manifest that those zones which have been esteemed desolate and waste, are habitable, inhabited and fruitful." From his "The Seaman's secrets," as quoted in A. Courtauld, *From the ends of the Earth* (London: Oxford University Press, 1958), p. 85.

[3] Polar bears have been observed on the ice near the pole while seals and shrimp are known to exist there beneath the ice and in leads.

[4] *Op. cit.*, p. 17.

Food Requirements and Sources in the American Arctic

Food Requirements

The amount of food needed by man varies with many factors, most of which are the same as those influencing the need for water; namely, age, weight, health, and activity. However, in the Arctic the voluntary caloric intake is greater than in the temperate regions.[5] It is the general consensus of students of arctic diet that ". . . cooks have to prepare ⅕ to ¼ more food per man than in temperate climates."[6] Thus, where a normally active person in a temperate climate will need from 3,500 to 4,000 calories, he will need 4,500 to 5,000 in the Arctic. This relationship is assumed to hold for the Eskimos as well as for non-natives. However, the consumption of the Eskimos is very difficult to estimate for there is great variation from day to day and season to season in their diet.

Assuming an unlimited food supply, actual food consumption varies with the amount of work done by an individual which includes the ". . . extra metabolic cost of activities caused by hampering action and weight of Arctic clothing."[7] This situation is well illustrated by Rodahl who, while making studies in the Arctic, examined the caloric intake of Greenland trappers. He found that the average consumption per man in the middle of the winter was 2,093 calories, about 1,200 calories less than their summer consumption.[8] He notes that "During the dark period of the year, when the food intake and calory consumption is at a very low level, the weather conditions usually prevent any exercise taking place."[9] Such periods of winter non-activity are quite frequent among non-natives in the Arctic. Most DEW Line personnel, for example, can spend weeks at a time in their building train without going outside.[10]

Some studies have been made of the relative proportions of carbohydrates and fats consumed under arctic conditions. In the case of the Eskimos, these properties vary greatly, especially with the season and the types and physical conditions of the animals consumed. In general, the reports on diets indicate that not only are high-fat-content diets not harmful but that they are preferred, for they are more effective in providing protection against heat loss than are low-fat diets.[11]

In recent years the demands of "well-rounded" diets by construction crews in the Arctic have brought the addition of tossed salads, garden vegetables, and fruit to the menus, all made of ingredients which have to be imported. For that matter, nearly all of the food consumed by most non-natives, and indeed many of the Eskimos, is imported today. Eskimos in pre-contact days were dependent entirely on the natural products of the region for their entire food supply. Such a condition is only partially true today, for all groups purchase some food and many purchase most of it at the trading posts and in their village stores.

Food Sources

Plant and animal life in the American Arctic, although not found on the ice-covered land areas,[12] is found in varying degrees of abundance on those parts of the land which are snow free for a period of time during the summer. It is found in the sea and on the ice floes floating thereon. Vegetation, although adequate enough to support herds of musk oxen on the world's most northern land, does not offer much food directly usable to man. The majority of the Eskimos only occasionally enjoy vegetable foods in their diet—traditionally, they are meat eaters. Sources of meat in the Arctic are varied. Land animals are present in most parts even though their density may vary greatly with the seasons. Sea mammals are available along most coasts and quite plentiful along some. It is among these mammals that the Eskimos find their most important food.

Sea Mammals; Types and Availability as Affected by Ice.

Seals. Many species of seal, most of them more or less migratory, are found in arctic waters. One of the least migratory of the seals, and certainly the most important one from the standpoint of the Eskimos' winter food supply, is the ringed seal (Phoca foetida).[13] This mammal is found in nearly all waters off the coasts inhabited by Eskimos, including northernmost Greenland where it is the only species present. It lives under the ice and, indeed, ". . . prefers the fiords that remain ice-covered the year round, . . ."[14] These seals, however, show a definite preference for certain ice conditions; they avoid areas of drift ice unless

[5] Johnson and R. Kark, "Environmental caloric requirements," *Federation Proceedings*, VI (1947), p. 138.
[6] Johnson and Kark, *Feeding problems in man as related to environment* p. 79.
[7] A. Burton and O. Edholm, *Man in a cold environment* (London: Edward Arnold, 1955), p. 181.
[8] "Vitamin sources in arctic regions," *Norsk Polarinstitutt Skrifter*, XCI (1949), p. 61.
[9] *Idem.*
[10] A frequently told story along the DEW Line has it that one individual was outside only twice during a tour of duty, once when he arrived at his base and once when he left.
[11] Burton and Edholm, *op. cit.*, p. 180.

[12] There are exceptions even to this statement. For example, at least 13 polar bears have been seen on the Greenland Ice Cap.
[13] Also, commonly called the rough seal, jar seal, fjord seal, and floe rat. All names, common and scientific, used for the sea mammals in this study are after Maxwell Dunbar, "Marine life," *Geography of the northlands*, chap. iii, unless otherwise noted.
[14] Wever, *op. cit.*, p. 31.

there is much water exposed.[15] Thus, they are generally present only in those areas protected from drift ice.

The bearded seal (*Erignathus barbatus*),[16] much larger than the ringed seal, is quite important in Eskimo economy. It does not have so wide a distribution as the ringed seal but does spend the winter under the ice in some areas. Whereas it maintains breathing holes,[17] there seems to be some doubt as to whether it actually makes these holes or whether it borrows them ready made from the ringed seal.[18] It, too, like the ringed seal, avoids old ice and drift-ice areas.

Other seals of varying importance to the Eskimos are the harbor seal *(Phoca vitulina)*, Greenland seal *(P. groenlandica)*, bladdernose seal *(Cystophora cristata)*, ribbon seal (*Phoca fasciata)*, and the fur seal *(Callorhinus ursinus)*, all of which tend to stay clear of an ice cover. They are therefore important only among the most southerly Eskimo groups or, if they are migratory (as is the important Greenland seal), among the northern groups in summer. These seals are generally not found in the areas where the highest development of ice hunting has evolved.

Seal availability in the Arctic during the winter depends upon, or varies with, ice conditions. The seal, being a mammal, must periodically surface in order to breathe. Those seals spending the winter in seas where a complete ice cover occurs must keep holes open through the ice in order to insure access to air. For a time after the ice begins to form, they can break the ice with upward bunts of their heads. After the ice becomes too thick (Stefansson writes four inches),[19] they must select a specific area in which to spend the winter where they can maintain holes through the ice.

Seals, by gnawing, keep several—as many as two dozen or so—of these holes open.[20] At the surface these holes are only an inch or two in diameter but they are enlarged beneath to an extent controlled by the thickness of the ice and the size of the seal. Seal breathing holes have been found in ice over seven feet thick with a resultant form often referred to as cigar shaped. Generally, the holes are covered by snow of variable thickness and are usually not visible from above. However, early in the season, after the surface freezes but before snow falls, breathing holes are open and relatively easily found. Then again, toward the end of the season, the snow may melt from the ice and reexpose them.

Occasionally, even during the winter season itself, strong winds will remove the snow from sections of the sea ice exposing the seal's breathing holes.[21] It has been observed that when the wind does clear the snow from one of the breathing holes the seal usually deserts it.[22] Desertion apparently is not sudden, for Mutch records that usually the largest hauls of seal ". . . come by chance, as when a hurricane sweeps all the snow from the ice, or clears great spaces from which they [the Eskimo hunters] can see the seals' breathing holes."[23] If, on the other hand, snow covers the seals' breathing holes too deeply, seal hunting, even with dogs, is practically impossible.[24]

The rate and time of ice formation vary greatly over short distances because of the great variability in shore-wind-water relationships. An excellent description of the effect such formation rates have on seal availability in Labrador fiords has been given by Tanner. He writes that

> . . . finally one morning the water was no more to be seen because of the frost mist. Everyone knew that the fiord was freezing, and that now the seal was moving to the channels and the bays, and the hunters started out. First the animals went to certain places in the bays; when these were blocked by the ice from the rivers and freeze with the increasing cold, the seal moved on to the channels kept open by the strong currents and there herds of the Greenland seal would remain.[25]

[15] Steensby, *op. cit.*, p. 69.
[16] The square flipper and ground seal.
[17] Birket-Smith, *The Eskimos*, p. 74.
[18] Wever, *op. cit.*, p. 32.
[19] *Arctic manual*, p. 448.
[20] Rasmussen, "The Netsilik Eskimos, . . ." p. 152. He writes that numerous holes are needed as the seal needs a wide area in which to obtain sufficient food but must remain within reach of a breathing hole. *Loc. cit.*

[21] Removal of snow from sea ice is not a general phenomenon, for snow on sea ice, unlike that on fresh-water ice, tends to stick.
[22] The reason is unknown, but an uncovered breathing hole is more easily discovered by the seal's predators than a covered one. Possibly more important is the fact that snow above the hole insulates the water beneath so that its freezing rate is decreased. The seal thus would have a minimum of work to perform in keeping the hole open.
[23] "Whaling in Ponds Bay," *Anthropological Papers—Boas Anniversary Volume* (New York: G. E. Stechert & Co., 1906), p. 492. Winds are important in yet another way. They control the extent of ice movement. On shore winds tend to drift ice toward the shore; offshore winds tend to keep the water near the shore ice free, at least, during the early parts of winter. Stefansson, in *My life with the Eskimo*, writes that off Cape Parry, for example, easterly or southeasterly winds keep the water open and the seals are plentiful. When however, the wind is from some other direction, or not sufficiently strong, water freezes over and seals and polar bears too, are not plentiful. p. 145.
[24] T. Harwood, "A further account of tragedy on the coast of Cumberland Gulf," *The Arctic Circular*, II (1949) reports such a condition in 1947 at Cumberland Gulf. The Eskimos had to resort to eating their dogs, which in turn reduced further their chances of normal hunting. p. 73.
[25] "Outlines of the geography, life and customs of Newfoundland-Labrador," *Acta Geographica*, II (1944), p. 494.

Seal availability is influenced by yet another shore-ice condition. Where coastal waters are shallow, as off the Mackenzie Delta and along the west coast of Hudson Bay, the water freezes to the bottom for great distances from the shore. If seals are present they must retreat beyond this zone of fast ice to relatively deep water. In the case of the Mackenzie area, retreat means a movement out to where the pack ice lies. There the seals must keep breathing holes open in the smooth ice between the stranded bergs.[26]

Although the seal is the most important sea mammal in Eskimo economy, there are other sea mammals of more than local significance. These include the walrus and the various types of whales found in the Arctic. As none of these animals maintains breathing-holes in the ice, there are many parts of the Arctic Ocean where they are not to be found. They are, thus, more seasonal in significance, being, with a few exceptions, limited to summer.

Walruses. The walrus[27] is found in Alaskan waters south of Point Barrow and in all of the waters of the northeastern Arctic except those off southern Greenland, southern Labrador, and in the southern part of Hudson Bay. It is absent from the waters north of central Canada. The walrus, of secondary importance among the Eskimos as a whole, is, for some groups, at certain times of the year, the most important food animal.[28]

Whales. The third of the large sea-mammal groupings of economic importance in arctic waters is composed of various members of the Cetacea. This order includes not only the whales proper but also the porpoises (*Phocaena phocaena*), narwhals (*Monodon monoceros*), and the belugas (*Delphinapterus leucas*) all of which are more or less frequent in arctic waters.

Various members of this order are to be found along all coasts inhabited by the Eskimos except those north of central Canada between Banks Island and Melville Peninsula. Jenness notes that such waters are too sheltered for whales, walruses, and belugas.[29] Exceptions to this distributional pattern may be found in the narwhal (reported as occurring in Prince Regent Inlet) and the Beluga (reported from Lancaster Sound).[30]

[26] Steensby, *op. cit.*, p. 126.
[27] *Odobenus rosmarus* (Atlantic walrus) and *O. Divergens* (Pacific walrus).
[28] Kane, *Arctic Explorations* . . . II, p. 130.
[29] D. Jenness, "The Copper Eskimos," *Encyclopedia Arctica* VIII (unpubl.), p. 3.
[30] Weyer, *op. cit.*, p. 37.

The two whales proper of greatest significance to the Eskimos are the

> . . . Greenland or arctic right whale (Balaena mysticotus), and the "bowhead" whale, a member of the same species, . . . These seem to be truly "ice-whales," always dwelling among scattered floes or about the borders of ice fields or barriers and seen in summer only where winter ice fields occasionally occur.[31]

They furnish many valuable products to the groups who hunt them including oil, the useful baleen (whale bone), and food—not the least of which is the prized "muktuk."

Whaling among the Eskimos, like nearly all of their occupations, is markedly seasonal in nature, being strictly a summer occupation. The duration of this season is quite variable. The shortest period probably occurs north of the Mackenzie Delta where whales are available for only a few weeks. To the west of this region, off Point Barrow, there are two seasons. In mid-April, when open channels begin to form in the ice, the whales pass Point Barrow on their journey east. This eastward movement lasts until about the end of June after which there are no whales north of Point Barrow until the end of August when they start their westward migration. The fall migration opens up another two-month season of whaling.

The smaller whales are often caught in the ice because of peculiar freezing conditions that frequently occur in certain parts of the Arctic. M. P. Porsild has written that

> Normally the ice covering of most of the fiords and open bays of west Greenland begins to form at the head of the fiords, where the glaciers and glacier rivers debouch, and thence gradually approaches the open sea. In Disko Bay, on the contrary, the phenomenon often is reversed; the ice covering begins when the drifting ice of Baffin Bay, the so-called "west ice," has approached the coast. . . . [it] often happens that schools of white whales or narwhals are cut off from the still open parts of Baffin Bay and are gradually driven in towards the head of Disko Bay.[32]

As freezing continues, these mammals are concentrated into small areas, and, because of low temperatures, their condensing breath produces clouds which are visible from great distances.

Land Animals. *Caribou: Availability and Distribution.* The caribou (*Rangifer arcticus*), the

[31] *Ibid.*, p. 36.
[32] "On 'savssats': a crowding of arctic animals at holes in the ice," *Geographical Review* XI (1918), p. 123.

most important wild land animal to the Eskimos, is found in nearly all of the American Arctic. Their greatest concentration apparently has always been in the Barren Grounds west of Hudson Bay, where a special Eskimo cultural pattern developed around them. Caribou, formerly quite numerous, were largely replaced in northern Alaska by domesticated herds; now these have decreased greatly in numbers and wild caribou are again by far the more numerous. Caribou have been present on all of the islands of the Canadian Archipelago, save the smallest, as well as along the whole of the coast of Greenland with the exception of Peary Land.[33] The number of caribou has been decreased greatly from what it was in earlier times, and their geographical range has been reduced.

Formerly, it was believed that all caribou migrated south for the winter, but it is now recognized that only part of them migrate and that the migration, for that matter, may not even be southerly. Any movement, however, is of great importance to the Eskimos or other hunters who have to govern their hunting accordingly. Stefansson writes that

> There is no sure way of telling when "migrating" caribou will arrive or just where they will pass. One thing that is known to affect the direction is the freezing of a lake—if caribou arrive before it freezes the herd will split to right or left or else the whole of it will be deflected to one side; if they arrive at a lake well frozen they make straight across. They might also be delayed by the late freezing of a body of water—hardly by a river, perhaps by a lake or a bay, certainly by a wide stretch of sea.[34]

Some caribou, however, remain on the islands throughout the year and have been observed migrating north during winter, rather than south.[35]

Snow characteristics have a bearing on the availability of caribou. A hardened snow crust which forms from wind packing or from sudden hard freezes after warm spells may cause the caribou to migrate to other areas. Caribou in most of the Arctic have to paw through the snow to the mosses and lichens beneath for their food supply. When a snow crust is present, digging is not only difficult but also dangerous, for the animals can easily cut their legs on the hardened snow. Caribou migrations resulting from such physical conditions have been known to bring about a general lack of food among some Eskimo groups.[36]

Depth of snow is an important factor affecting caribou grazing habits and therefore caribou hunting grounds. Snow in the Arctic is generally somewhat deeper in low areas than on higher more-exposed sections. This decrease in snow depth with exposure apparently accounts for the decided preference of caribou for high ground and hills, and must more than offset the fact that exposed snow becomes more wind packed than protected snow.

Lack of snow cover, or even a delayed season, is important. Among the people of Labrador, for example, the hunting of caribou in the fall is not so important as it is in spring, because ". . . in October there is often no snow on the ground yet and therefore game must then often be carried."[37]

Other Land Animals. Caribou, although the most important land animal available, is not the only one. Others, including the musk ox, polar bear, wolf, fox, and various rodents, become at times very significant items of diet. They may also be hunted for some purpose other than food, a fact that became especially true of the fox after demand for its fur made itself felt.

The musk ox, the only other large arctic grazing animal besides the caribou, formerly had a rather wide distribution but is found today in relatively few places. Most of them are found on the northern islands of the Canadian Archipelago, although there are still a few in continental Canada and northeastern Greenland.[38]

The polar bear, found on the sea ice throughout much of the Arctic Ocean and on the adjacent land, is quite seasonal in significance. It is of major importance in winter when pack ice is tied to the land; summer occurrence depends mostly on closeness of pack ice.[39] During the fall, great numbers are present on the sea ice several hundreds of miles from land, migrating frequently into the camps of the drifting ice stations.

[33] Stefansson, *Arctic manual*, p. 73.
[34] *Ibid.*, p. 78.
[35] Wever, *op. cit.*, p. 40. Not only have the large caribou herds of north central Canada been reduced in number but patterns of seasonal movement have changed. Baird writes that the great migrations across the ice to and from Victoria Island have nearly ceased. "Canadian Arctic Archipelago," *Geography of the northlands*, chap. XVII, p. 364.

[36] See Bilby, *op. cit.*, p. 40 for an example.
[37] W. Steinert, *Die wirkung des landschraftszwanges auf die materielle culture der Eskimo* (Hamburg: Ph.D. dissertation, 1935), trans. A. Herling, ADTIC, Maxwell Air Force Base, p. 55. Tanner, *op. cit.*, writes that "The Jesuit Chronicles tell of several cases when famine has ravaged large areas because there has been little snow." p. 621.
[38] Baird, *op. cit.*, p. 353. These animals have been depleted to such an extent that they are now protected by law.
[39] Stefansson, *Arctic manual*, p. 93.

The smaller animals, such as wolves, foxes, and various types of rodents, are widely distributed over those parts of the Arctic occupied by the Eskimos. Wolves are most frequently found in the company of caribou, whereas foxes are common on the sea ice where they trail the polar bears.

Birds; Availability and Distribution. The bird life of the Arctic is quite varied and very seasonal. Of the great numbers of species spending the warm season in Eskimo territory, or poleward thereof, very few remain throughout the winter. The most important of these winter dwellers is the ptarmigan *(Lagopus spp.)*. During summer great numbers of birds[40] nest in the Arctic, where they can be found in all types of environment, including water, land, and ice.[41] It is these groups of migratory birds that are of the greatest significance as game to the Eskimos. They include numerous types of geese, ducks, gulls, and loons. Birds are hunted by all Eskimo groups, but their importance varies greatly from one group to another. Birds furnish meat, eggs, skins, and down, although all of these products are not used by many Eskimos. Among some groups they form a basic item of diet during certain seasons of the year, and among some they are stored for future use.

Snow and ice are important in that they affect bird availability. The time of appearance of the migratory birds in the Arctic varies greatly with different species, but in general it is prior to the complete melting of snow from the land or of ice from the lakes.[42] In general ducks and geese migrate along rivers and coastlines. Stefansson writes that at Camp Hallkett about the first of June the

> . . . sea ice is of course snow-white and so is the land back from the shore, but the cut banks along the beach are dark. The migrating geese coming from the west follow the dark line of the cut bank as cows do a winding trail. . . . This is especially true in thick foggy weather.[43]

The amount of snow on the ground and the rate at which it melts will affect the occurrence of birds, a condition which is illustrated by Anderson. He reports that near the Horton River,

> . . . when the winter's snowfall was light and consequently melted away quickly there was very little goose-shooting in the spring. If there is little snow on the ground when the geese arrive, they stay only three or four days and head out seaward. . . . If the ground is snow-covered, the large flocks sometimes stay for a long time. . .[44]

The time of the return migrations varies greatly with different bird types, also. Several types remain in the Arctic as long as possible because their young " . . . only begin to fly late in the season. The parent birds try to feed them in small pools and channels . . ."[45] Porsild writes that "Eider ducks are often seen at the beginning of winter crowded in hundreds in relatively small openings, . . ."[46] At the time of departure many of the young are not yet completely ready for flight and ". . . cannot always keep up with older birds, and frozen eider-ducks, especially young birds are often seen lying on the ice of the Arctic Ocean"[47]

Such long delays in departure time mean that the birds have to fly in adverse weather conditions. They often become covered with frost which makes them aerodynamically unstable and relatively easy to capture.

Some birds are surprised by the sudden freezing of the sea and become trapped, often flocks of thousands being crowded into small openings.[48] If these savssats occur near the shore all the birds involved may be captured before the water in the hole completely freezes. If, on the other hand, the hole is far from a settlement the birds will gradually freeze. Porsild describes lucidly one such instance that occurred in west Greenland in the winter of 1908-9. The original hole

> . . . had a diameter of over a mile; when I passed, the whole field was covered with ice, rather thin but safe enough for sledging. Over it could be seen elliptical humps of ice, some of

[40] The great number of birds present in the Arctic in summer has been mentioned by many authors. Two quotations might illustrate. "The coasts [Ellesmere Island] are enlivened by many kinds of sea birds, . . . and in places these make even the barren Silurian limestone soil fertile." Mordenskjold and Mecking, *The geography of the polar regions* (New York: American Geographical Society, 1928), p. 231. Stefansson in *The friendly Arctic* writes that "The ground at moulting season in some islands such as Banks Island, . . . is literally white with millions of wavy geese . . ." p. 18.

[41] Mecking reports that Koch saw two species of birds in the middle of the inland ice of Greenland as did also Nordenskiold and Nansen. Nordenskiold and Mecking, *op. cit.*, p. 244.

[42] In many instances the appearance of the birds and the disappearance of the snow must be quite close in time. Mecking writes that in northeast Greenland ". . . the snow melted away in one day; the birds all arrived almost the same day, . . ." *Ibid.*, p. 274.

[43] *My life with the Eskimo*, p. 382.

[44] "Report on the natural history collections of the expedition," in Stefansson, *My life with the Eskimo*, p. 466.

[45] Otto Sverdrup, *New land: four years in the arctic regions* (London: Longmans, Green, 1904), II, p. 65.

[46] Porsild, *op. cit.*, p. 224.

[47] Sverdrup, *loc. cit.*

[48] Porsild, *op. cit.*, p. 224.

them with a small fissure at the top, through which the heads of the birds protruded.[49]

Fish; Availability as Affected by Ice. Fish life in the Arctic is represented by very few species,[50] of which the arctic char *(Salvelinus alpinus)* is the most important food fish. Locally, however, other fish may be more important than the arctic char. For example, around the Mackenzie Delta the whitefish *(Leucichthys lucidus)* is the most common food fish.[51] The number of species is much greater in the subarctic waters, however, and includes various types of cod and halibut as well as caplin and the Atlantic salmon. Of these, the Greenland cod and arctic halibut extend into the edges of the arctic zone. Some of these subarctic species have been the backbone of great fisheries since the days of Cabot. Most of these fish, however, do not penetrate far up Hudson Strait and Hudson Bay itself does not contain any great quantity of fish. Lakes and rivers in the Arctic often contain large numbers of fish, fish which under intense fishing are easily depleted because of the slow rate of growth.

In the Arctic the migration of fish is often associated closely with ice formation. The salmon trout (arctic char) of the eastern and central Arctic move into the lakes from the ocean in late summer and spend the winter under the ice there. Some of these fish become trapped in ponds in shallow river sections which freeze to the bottom. They are cut out of the ice in the spring by various Eskimo groups. Other fish find their way into deep lakes or deeper parts of the river, where they are concentrated, providing good fishing. Toward the end of spring when the lake ice begins to break up, a reversal in migration takes place. The salmon and other fish which have spent the winter in the lakes begin moving out to sea. These are concentrated in the narrow leads and in ". . . some places they are so plentiful as to fill the water completely."[52] Rivers that have deep mouths where they drain into the ocean continue to flow throughout the winter underneath the capping river ice. Fish will not be plentiful under such conditions because of the free access they have to the sea.[53]

Most surface water in the Arctic freezes during the winter, whether it be the surface of lakes, rivers, or the sea. There are some streams and straits which, because of rapidly flowing water, may remain open throughout the winter. A quite frequent location for such open water is where lakes debouch into streams. Such open patches during winter frequently have great concentrations of fish.

Sea ice formation affects fish availability, also. In late summer when the shore ice first begins to form, narrow tide cracks appear along the edge of the beach and often contain high concentrations of fish.[54] At the beginning of the summer season the same phenomenon also often occurs. As the ice begins to break up along the shore, fish begin to return under the ice to shore waters. Unlike the unfavorable conditions in the spring, however, fishing can be carried on with the ice as the base of operations where holes can be made through it and fish taken on their way to the shore waters.[55] This type of fishing, especially important among the Bering Strait Eskimos, is the main type among the Polar Eskimos.[56] These early summer shore leads tend to concentrate those fish migrating from the lakes back to the sea, as well as those moving toward the shore from deeper waters. The fish going back to the sea tend to stay in the leads or just under the edge of the ice.

The nature of the sea ice influences fish concentration. When it is broken and hummocky, fish are scarce. When, however, there is a ". . . large field of the season's ice, 3 or 4 feet thick, inclosed by hummocks, . . ." fish may occur in great numbers.[57] Success in ice fishing varies greatly. During certain times and in certain localities, fish are caught nearly as fast as the fisherman can work.

Vegetation. As the tree line, with few exceptions, has been adopted here as the southward and landward limit of the Arctic, the area's vegetation is non-arboreal. Nevertheless, except for those areas covered with a permanent ice cover, vegetation constitutes a part of nearly all arctic landscapes. The flora varies greatly in density and composition and possesses representatives of

[49] *Idem.*
[50] Wilimousky in "The utilization of fishery resources by the Arctic Alaska Eskimo," *Occasional Papers of the Natural History Museum of Stanford University*, II (1956), writes that northern Alaska has about 50 fish species of which 40 percent are used as food, p. 1.
[51] Anderson, *op. cit.*, p. 451.
[52] Boas, *The Central Eskimo*, p. 514.
[53] Murdoch, *op. cit.*, p. 58.

[54] *Ibid.*, p. 278.
[55] Nelson, *op. cit.*, p. 184.
[56] Birket Smith, "The Greenlanders of the present day," p. 132.
[57] Murdoch, *op. cit.*, p. 283.

the lichens, mosses, grasses, and flowering plants. Exposed bedrock may possess only a scanty cover of lichens but, on the contrary, parts of the tundra, in season, have a thick, varied plant cover. Only a few arctic plants possess parts edible for man. Nevertheless, all Eskimo groups eat (although rarely) some plant portions, including roots, stems, leaves, and berries, the best of which are found in the southern reaches of the tundra.[58] Indirectly, most plants are very important in the Arctic for they provide the basis for the caribou as well as other land animals.

[58] A. E. Porsild, "Edible plants of the Arctic," *Arctic*, VI, no. 1 (1953), p. 15.

Food production; Eskimo Hunters and Sea Mammals

Birket-Smith, in his book *The Eskimos*, writes:

> It is the sea rather than the land that on the whole conditions the life of the Eskimos. . . . The large acquatic mammals—seal, walrus, and whale—provide them with their most important food. . . .[59]

Among the Eskimos, there are only two groups—the Caribou Eskimos (and only certain "tribes" of these) and the inland Alaskan Eskimos—whose hunters do not pursue sea mammals during some season of the year. In general, the sea mammals are somewhat more important to the Eskimos during the winter season than during the summer.[60]

Seals; Ice Conditioned Hunting

Of the sea mammals used as food, the seal is the most important; and about it a distinctive set of ice hunting techniques has developed. So important in Eskimo culture is the seal that Boas once wrote that it ". . . enables man to withstand the inclemency of the climate and the sterility of the soil."[61]

The great variations in ice conditions prevailing in the Arctic and the correlation of sealing methods with these conditions is indicated by Birket-Smith in his statement regarding the west coast of Greenland:

> In southernmost Greenland there is only a short period in the winter when sealing cannot be carried on from kayaks, and it is rarely for any length of time. . . . The winter ice puts obstacles in the way of this occupation in a few places only; but the farther north we get, the more solid and more lasting the cover of ice, until in the Thule District it extends over three-fourths of the year. Seal and walrus are then hunted from the solid ice.[62]

Seals are hunted by the Eskimos under three contrasting situations: when the seals are in open water, under the ice, or on the ice. The main weapon used is the harpoon (replaced generally in recent years by the gun), although some groups have adapted nets to sealing. In the use of harpoons and nets, the Eskimos have devised several special procedures which take advantage not only of the seal's variable habitat but also of its habits.

The numerous seal-hunting methods considered on the basis of these variables might be summarized as follows:

I. Under-ice hunting
  A. At the breathing-hole
    1. Maupok method
    2. Net
  B. "Peep-hunting"
  C. Ice edge with net
II. On-ice hunting
  A. Stalking
    1. Smooth-ice with harpoon (gun)
    2. Utok method with harpoon (gun)
  B. Young-seal method
III. Open-water hunting
  A. From ice edge with harpoon (gun)
  B. From kayak with harpoon (gun)

All of these types of seal hunting make valuable use of, and are made possible by, the conditions of the ice—with the exception of hunting from a kayak. In kayak hunting, ice, while it may occasionally be used to advantage, is generally a hindrance.

[59] P. 73.
[60] Wever, *op. cit.*, p. 111.
[61] *The Central Eskimo*, p. 419.
[62] "The Greenlanders of the present day," p. 121.

The several types of breathing-hole methods of seal hunting are those best adapted and adjusted to winter conditions, and of these the maupok[63] method is best adapted to the need of the seal to surface periodically in order to breathe. It is not the most lucrative on an absolute basis; but among many Eskimo groups, it is the only method of staving off starvation during the winter.

The Maupok Method. The objective in maupok hunting is to harpoon a seal as it rises at a breathing hole to replenish its supply of air. It is a method which is basically the same wherever it is practiced, varying only slightly in procedure and in the equipment used throughout the Arctic. The basic requirement for the successful operation of this method is complete ice cover over an area of the sea where seals spend the winter.

The general procedure followed in maupok hunting has been described many times and for most groups of Eskimos, but possibly the most complete description is that given by Mathiassen for the Iglulik Eskimos. Generally an Iglulik hunter uses a dog to help him locate a breathing hole, for it usually can be located only through the sense of smell. After a breathing hole has been located and the dog tied up,

> . . . the hole must be examined to ascertain whether the hole has been recently used, and to find out the shape of it; the hole searcher is used for this purpose. . . . After thus having found that the hole has recently been used by a seal and the middle has been determined, the hunter builds himself a small shelter-wall of blocks of snow if it should be windy, . . . a block of snow serves as a seat. . . . The harpoon is laid by his side on the two rests and a knife is stuck into the snow. The seal indicator is placed vertically in the hole and fastened to a stick (oftenest the seal hook), inserted obliquely into the snow by the side of the hole. If there is a very thick layer of snow on the ice, the hunter may use a wad of eiderdown or of hare fur which he presses a little way into the hole and, by means of the pressure of air when the seal comes, is blown into the air; the wad is fastened to a thin cord, the other end of which is tied to the knife or frozen fast to the ice.[64]

The hunter, ready for the seal, waits quietly[65] until the seal indicator moves. He then thrusts his harpoon through the center of the breathing hole into the seal. As the breathing hole is small at the surface, it has to be enlarged before the seal can be pulled out, its wounds plugged (in order to conserve the blood) and dragged to the sled.

Although this general procedure is used wherever this type of hunting is carried on, there are some variations. Dogs are not always necessary, for the seal breathing hole, even though covered with snow, will frequently be indicated by a slight elevation which has resulted from the rime left by the seals' breath. Rasmussen did not consider this indication of much value and wrote that

> Finding a breathing hole without the aid of a dog is a matter of pure chance; not only is it difficult to discover, but there are not many of them. But sometimes the foxes form a guide, for they often place their excrement on the ice dome.[66]

Once a stand at a hole has been taken, the possibility of a long wait is anticipated. The length of wait varies greatly as do the methods of waiting.

> If the Eskimo expects the early return of the seal, he spreads a small piece of skin, generally that of a young seal, close to the hole and places his feet upon it, thus keeping them warm.[67]

An additional function of the seal-skin footpad has been suggested by Rasmussen. He thinks it helps prevent excessive creaking of snow, the sound of which would frighten a seal away.[68] When a longer wait is anticipated, more elaborate arrangements are made. These generally include a wind break (nearly always made of snow blocks), a snow seat[69] and a rest for the harpoon. Harpoon rests are often two pegs stuck in the snow, but many hunters prefer to hold the harpoon across their knees.[70]

Other maupok hunting equipment frequently includes: (1) an ice pick which is used for opening

[63] The maupok method is often referred to as the "breathing-hole method" in the literature. In this paper, the term "breathing hole" is applied to any technique used at breathing holes, as outlined above. The maupok method refers specifically to the harpooning or shooting of a seal at its breathing hole after waiting for it to come up and breathe.

[64] *Op. cit.*, p. 43.

[65] Rasmussen in "The Netsilik Eskimos, . . ." writes that when a seal ". . . breathes there is a noise of blowing, and while this is going on the seal does not hear very well, whereas its sense of hearing is extremely keen when under the ice near the breathing hole but without blowing. The very slightest crunching of the snow will drive it away . . ." p. 152.

[66] *Ibid.*, p. 157.

[67] *Idem.*

[68] Rasmussen, "The Netsilik Eskimos, . . ." p. 156.

[69] In Greenland and Alaska stools are used to sit on while sealing. Birket-Smith, *The Eskimos*, p. 83.

[70] Birket-Smith, "The Caribou Eskimos, . . . I. Descriptive part," p. 127.

the hole so that it can be examined and for opening the hole to pull the seal out, (2) an ice scoop to use for scooping pieces of ice or slush out of the hole prior to arranging the seal indicator, and (3) a skin protector with which the hole, through which the harpoon is to go, is covered during snowy weather.[71]

Maupok hunting is generally carried on at breathing holes made by the seals being hunted, but artificial breathing holes have been reported. Ostermann describes a method the Eskimos use at Point Hope:

> Early in spring they find a place frequented by seals in the ice; there they cut a hole and make a breathing hole exactly like those the seals make. It is left alone for a day or so, and if then it is found that a seal is using it, they watch by it.[72]

The maupok method, used from Greenland through Alaska, has been most highly developed about the Northwest Passage.[73] The Coronation Gulf presents such favorable ice conditions for this type of hunting that entire villages are moved out onto the ice. These villages, located at the center of a chosen sealing area, are, according to Stefansson, ". . . built as nearly as possible in the middle of the gulfs and straits, . . ."[74] The smoothness of the ice helps determine the actual location of the camp, for the smoother the ice the more easily seal breathing holes are found. From this centralized location, the hunters spread out daily. Over a period of time they hunt out to a maximum of about five miles. Thus, a village will live off the seals found in a circle of ten miles diameter. In a month or so, the seals within this area are depleted to the extent that the village is moved to some other site at least ten miles distant.[75] This type of hunting is of greater significance to most of the Northwest Passage Eskimos for two reasons. First, the period of solid-ice cover is of long duration, and, second, summer and early fall sealing its generally not practiced, for many Eskimo groups spend these seasons inland. In fact, some of these groups, such as the Netsilik, are unfamiliar with open-water hunting.[76]

Maupok hunting, practiced throughout the winter in the Northwest Passage, is generally utilized for only a few days at a time during early winter at unfavorable locations such as Point Barrow. A favorable condition prevails at Point Barrow when the sea freezes prior to the pack's drifting in toward the shore and when holes and leads in the pack itself freeze sufficiently to hold a man. These smooth ice areas are continually being broken and reduced in size until breathing holes become very scarce. By January, at the latest, such smooth ice areas are so small and scattered that maupok hunting can no longer be practiced.[77]

Most maupok hunters depend upon the seal to come to the hole where the hunter has taken his stand. At times, however, the Eskimos try to control this selection and thus reduce the length of wait. In Pelly Bay toward ". . . the end of May the dome over the breathing hole melts and the opening is fully exposed in the ice. They are no longer difficult to find. . ."[78] In such a case,

> All breathing holes in a wide circle are beset by children and women, who scare the seals away when they appear; at last they go exhausted to the hole at which the hunter is waiting.[79]

In Greenland, during this same season, the hunter, when he finds a hole which seems to be in use, sends a boy

> . . . on with the sledge; the dogs smell out the other breathing holes in the neighborhood, and the boy destroys these with a kick. The s dares not come to the surface in those h but resorts to the one where the hunter i ail-ing.[80]

Yet another procedure is to have a boy drive a sledge in a wide circle around the hunter in order to frighten the seals toward the hole where the hunter is watching.[81]

In recent years a new technique has been introduced into some parts of the Arctic which has the advantage of relieving the hunter of his wait

[71] Rasmussen, "The Netsilik Eskimos, . . ." p. 155.
[72] "The Alaskan Eskimos as described in the posthumous notes of Dr. Knud Rasmussen," *Report of the 5th Thule Expedition, 1921-24*, X, no. 3 (1952), p. 120.
[73] Birket Smith, *The Eskimos*, p. 81.
[74] "The distribution of human and animal life in western arctic America," *The Geographical Journal*, XL, no. 5 (1913), p. 454.
[75] Steensby, *op. cit.*, p. 123.

[76] Rasmussen, "The Netsilik Eskimos, . . ." p. 151. Rasmussen in "Intellectual culture of the Iglulik Eskimos," writes that the Iglulik Eskimos do not engage in sealing as early in the season as they could because of certain taboos they have established. As long as their snow huts are on the land they cannot hunt seals and they cannot move their villages out on the ice until their winter clothes have been made. p. 192.
[77] Murdoch, *op. cit.*, p. 269.
[78] Rasmussen, "The Netsilik Eskimos, . . ." p. 159.
[79] Mathiassen, *op. cit.*, p. 44.
[80] Birket Smith, "The Greenlanders of the present day," p. 123.
[81] Mathiassen, *loc. cit.*

at the breathing hole. Manning observed some Wager Inlet Eskimos mounting a rifle on a tripod over a breathing hole. When the trigger was set off by the rising seal a harpoon was fired into the seal.[82] Helmericks writes that the same procedure is used in the Mackenzie area except that there a "snowhouse" has to be constructed around the tripod, for the wind whistling about the tripod's legs would otherwise scare the seals away.[83]

Possibly an early Eskimo version of this same practice is that described by Sonnenfeld. The hunter

> . . makes a trap utilizing harpoon and ice. . . . A weight either of stone or ice, is placed on top of the shaft. . . . If an ice block is used, the end of the harpoon shaft is placed in a hole chipped five inches into it. Water is poured around the opening to freeze the shaft in solidly. The whole is then set up vertically in an ice block frame, so that the harpoon sits poised directly over the breathing hole. The frame consists of four narrow ice slabs about three inches thick set up on end. These act as a retaining wall for the harpoon weight. The ice is built up on one side of the breathing hole, and the harpoon head rests precariously on the edge of this, the point projecting into the hole, just above the water. A thong attached to the top of the shaft, and extending through a hole in the ice brick, has its outer end staked into the ice. As the seal comes up to breathe it touches the point, unseating it, and the whole harpoon—shaft, and weight on end—shoots down. The enclosure acts like a rifle barrel, directing the weighted shaft, and the seal is "harpooned." [84]

"Peep-hunting." Maupok hunting is generally used where there is a complete ice cover and seals remain beneath the ice. Two other methods used under the same conditions include specialized netting and the so-called "peep-hunting." This type of hunting is practiced by the Eskimos in Greenland and around the magnetic pole. The method used in this hunting has been described by Birket-Smith as follows:

> Two holes are hewn in the ice side by side. At the smaller stands one man with a harpoon, ten or more yards in length, that is held down in the water. At the other hole lies another man, with a cover above his head, peeping down under the ice and with one hand guiding the harpoon held by his fellow-hunter. He whistles and whispers, and at the same time the harpoon is moved up and down slightly, thus making two small pieces of bone, that are fixed near the harpoon head on split-feather shafts, vibrate. This is more than the seal can stand. A cautions *ke!* or *keq!* comes from the watcher when the seal in under the harpoon, a thrust—and it is caught.[85]

Stalking Methods. Other types of ice hunting are concerned with the breathing hole but, unlike maupok and peep-hunting, they do not require waiting at the breathing hole itself. They generally involve a stealthy movement over the ice to the vicinity of the seal's breathing hole where it can be dispatched, either in the hole itself or on the ice near the hole.

"Smooth-ice Hunting." When ice first forms it may remain for varying lengths of time without a snow cover. This lack of snow facilitates a type of early breathing-hole hunting, for the breathing hole itself is not protected and the breathing of the seal can be heard a long distance. At this time, the hunter can also proceed over the ice with a minimum of noise.

In order, however, to decrease this noise even further, the hunter ". . . ties on a pair of sandals of polar bear skin or longhaired dog skin . . ."[86] Guided by the seal's breathing, the hunter moves toward the seal only when it is snorting at the breathing hole, which the seal does about eight times at each appearance[87] The hunter, by using such caution, is able to move gradually up to the seal where he can harpoon it.

Smooth-ice hunting is engaged in by all breathing-hole hunters who have the opportunity, and it is considered a pleasant occupation among them.[88]

Utok Hunting. Whereas smooth-ice hunting may precede the maupok season, another relatively distinct type of hunting follows it. This is the utok method, a method that takes advantage of the fact that as spring advances seals begin to come out on top of the ice to bask in the sun beside their breathing holes.

The special techniques used in utok hunting are all geared to methods of approaching the seal over the ice so as not to frighten it back into the

[82] "Hunting implements and methods of the present-day Eskimos of the north-west Hudson Bay, Melville Peninsula, and south-west Baffin Island," *Geographical Journal*, CIII, no. 4 (1944), p. 142. Murdoch, *op. cit.*, noted the use of the gun at the breathing hole in a different fashion. The Point Barrow Eskimos used it to shoot the seal through the head as it came up to breathe. The harpoon was used only to retrieve the seal. The current, however, often carried the seal away before it could be retrieved. p. 269.

[83] *Arctic hunter* (Boston: Little, Brown and Co., 1955), p. 48.

[84] *Changes in subsistence economy among Point Barrow Eskimo* (unpubl. Ph.D. Dissertation, Dept. of Geography, Johns Hopkins University, 1957), p. 53.

[85] *The Eskimos*, p. 82.

[86] *Ibid.*, p. 80.

[87] Mathiassen, *op. cit.*, p. 45.

[88] Birket-Smith, *The Eskimos*, p. 80.

breathing hole. A hunter's success at this endeavor depends to a large extent on the condition of the snow cover. These techniques were more highly developed in the days prior to the introduction of the rifle but are, even today, used to great advantage.

As it is almost never possible to utilize natural concealment in seal hunting, the approach to the seal is always from the leeward, an adaptation to the fact that the seal has good hearing but poor eyesight. Two approaching techniques are used, both of which are adapted to the seal's napping habits and snow conditions. As the seal lies sleeping, the hunter can advance. The sleeping period is very short, being only a half-minute or so, followed by a period of waking. During this period, the seal examines his surroundings, and then the hunter must be able to convince the seal that nothing is amiss. In order to do this, the hunter may use some form of artificial concealment or he may try to convince the seal that he is another seal out basking in the sun.

In the concealment technique the objective is for the hunter to wear something that will cause him to blend in with the white environment.[89] The Greenland and Baffin Island Eskimos prefer what is referred to by Birket-Smith as a "shooting-screen".[90] It is ". . . a piece of white cloth stretched in front of a small sledge, which [the hunter] pushes along in front of him, crawling along the ice.[91] While this method is also used by the Alaskan Eskimos,[92] they prefer a somewhat different technique. The Alaskan hunter ". . . camouflages himself with a cap and mittens reaching above the elbows, of polar-bear fur; . . ."[93]

The most frequently used technique in utok hunting is when the hunter, wearing sealskin clothing, tries to convince the seal that he is of the same species. In order to do this, the hunter imitates the seal's movements and even its bark. Deception is carried a step farther in Alaska and Greenland, and possibly elsewhere, where scrapers made of seal's flippers are used. Such imitations are so convincing that a hunter often can advance right up to the seal. To make the approach easier a Central Eskimo hunter fastens ". . . a piece of skin under his left arm, upon which he reclines. The skin protects him from melting snow, facilitates speed, and diminishes the noise as he creeps."[94]

The approach to the seal, in the days before guns, had to be close enough to harpoon it. Often the harpoon was equipped with an extra long shaft and used like a spear. Today, most utok hunters use a rifle, but even with this long-range weapon a close approach is advantageous. The seal generally basks very close to its breathing hole and, if not killed outright, will be able to get back into the water before being reached by the hunter. Occasionally even those killed outright are given sufficient momentum to slide them over the slippery ice into the hole.

The weapon used on these basking seals was not always the harpoon. Rae, according to Mathiassen, mentions ". . . that the women at Repulse Bay were skilful [sic] at crawling up to seals and killing them with a small club."[95]

The state of the ice and snow is very important in the success of this method of hunting. It has been stated that when the snow is hard without any water on the surface a seal can be killed in less than a half-hour. On the other hand, if the snow is soft and deep it is hard to push oneself along the surface and almost impossible to get near enough the seal to kill it.[96] Manning notes that, under such conditions, the obvious trail left behing in the snow also tends to frighten a seal.[97]

Young Seal Hunting. In the spring yet another form of seal hunting is practiced. It is the hunting of young seals which is made possible by the pregnant females who make an excavation on the ice surface under the snow where they bear their young. The Eskimos hunt these seals by using dogs to locate the dens. Once a den is located the hunter breaks in the roof and cuts off the retreat of the seal. Boas remarks that generally the mother escapes but that the pup seldom does.[98] A variation of this technique is practiced in the Bering Strait area. Nelson writes that the seals come up through holes in the ice to have their

[89] Stefansson writes in the *Arctic manual* that, because the polar bear is the big natural enemy of the seal, "It would not serve the hunter to pretend he is a bear. . . . you must not wear white clothes . . . ." p. 452.
[90] *The Eskimos*, p. 83.
[91] *Idem.*
[92] Nelson, *op. cit.*, p. 130.
[93] Steinert, *op. cit.*, p. 82.

[94] Boas, *The Central Eskimo*, p. 484. Rasmussen in "The Netsilik Eskimos. . . ." notes that this skin among the Netsilik is ". . . either a sealskin or a piece of bear skin . . ." for their clothing is made of caribou skin which does not slide easily in snow and in the late spring becomes soaked easily, p. 169.
[95] Mathiassen, *op. cit.*, p. 45.
[96] Boas, *The Central Eskimo*, p. 484.
[97] *Op. cit.*, p. 143.
[98] *The Central Eskimo*, p. 482.

young. "These holes are sometimes covered by the hunter with an arch of snow, and the seals are surprised and speared as they come up."[99]

Nets. The net, as well as the harpoon and gun, is used extensively in true ice sealing. Its use does not require the patience needed of maupok or utok hunters nor the skill needed by kayak hunters but it is, at times, more productive than any of the other methods. Birket-Smith writes that the use of nets is of Eskimo origin but that it was very little used prior to colonization, except in Alaska.[100] In Alaska aboriginal net hunting was as important and skilled as maupok hunting is in the Northwest Passage. It rapidly increased in importance in Greenland after colonization and became the principal form of winter sealing, replacing maupok hunting in many localities.[101] The use of the net in ice hunting varies greatly in Greenland, being more important in the northwest than in the southwest. Around Holsteinborg, for example, the net is set under the ice but is not so productive as it is farther north. Holsteinborg is at the southern limit of the sledge and ". . . this means of conveyance cannot be used so freely as to permit the Greenlanders to tend as many nets as are necessary in order to make sealing really profitable."[102]

The netting of seals under the ice is practiced in more ways among the Alaskan Eskimos than among any of the other Eskimo groups. Off Point Barrow, netting of seals begins about the middle of November and is the most important "fishery" of the year. Murdoch described the procedure they use, which has been paraphrased below. This method can be successfully engaged in only on the darkest nights. At a place where level, relatively thin, ice extends back from the lead about 100 yards, several nets are hung under the ice parallel to the lead. Noises made by the hunters on the ice behind the nets cause the seals swimming about in the lead to dive under the ice to investigate, thus becoming entangled in the net.[103]

The ordinary Alaskan method of setting these nets under the ice[104] is to thread them through a series of holes, the middle one of which is large enough to pull an entangled seal to the surface. In Greenland the procedure is basically the same, although usually the hole nearest the entangled seal is the one chopped open.[105]

This type of sealing may be very productive. Murdoch records that the netters of one village have taken as many as 100 seals in one night.[106] Such hauls are generally considered "lucky," however.

In the Point Barrow area this type of sealing ends with the closing of the leads by the January gales. Such closing does not mean, however, that netting is ended, for cracks occur throughout the winter among the hummocks. The Eskimo hunter hangs nets ". . . around these cracks, so that a seal can not approach the crack without being caught."[107]

Nelson has described a third type of net sealing which is actually a specialized type of breathing-hole sealing, used from Bering Strait to Point Barrow. This technique is carried on during the dark winter nights, and proceeds as follows:

> The blowholes of the seals are located during the day; at night the hunters go out and make four holes in the ice, in the form of a square, at equal distances from the seal hole; a square net is then placed under the ice by means of a long pole and a cord. . . . When the seal rises to breathe it becomes entangled in the net and is captured.[108]

Procedures calculated to increase the yield and also to make seal netting easier have been devised by the Eskimos. For example, the central breathing hole may be protected by an ice cap which keeps the water from freezing overnight. Such a cap is functionally important in yet another way. It ". . . is hollowed to increase reflection and light coming into the hole, so that it is easily found by the seal."[109] Such a procedure will work in netting seals at breathing holes, whereas just the opposite conditions are necessary for netting seals along leads. The objective at leads is to entice seals away from the leads into the nets and requires darkness to be successful.

Seal Hunting at the Edge of the Ice. In those areas where ice does not form a complete cover, seals will generally be found, not under the ice, but in the open water. They may be lured under the ice, as described above, but more frequently they are hunted as they swim in the open water.

[99] *Op. cit.*, p. 129.
[100] "The Greenlanders of the present day," p. 108.
[101] Steensby, *op. cit.*, p. 92.
[102] Birket-Smith, "The Greenlanders of the present day," p. 108.
[103] *Op. cit.*, p. 270.
[104] According to Murdoch, *op. cit.*, nets for seals are also set in shallow water along the shore in summer, p. 251.
[105] Birket-Smith, "The Greenlanders of the present day," p. 126.
[106] Murdoch, *op. cit.*, p. 270.
[107] *Ibid.*, p. 271.
[108] *Op. cit.*, p. 270.
[109] Sonnenfeld, *op. cit.*, p. 59.

In many areas the kayak is used; in others, however, hunting is carried on from the ice. This type of sealing is so important to some groups that their main food supply, during certain seasons, results from it. It can be carried on ". . . at the edge of the solid winter floe, at lanes and holes in the ice caused by currents, or from the drift ice . . ."[110] Probably the best all-round situation for sealing is when narrow leads are present, leads varying in width from 20 to 100 yards.[111]

As the ice begins to form in the fall and ". . . newly formed floes drift to and fro in the open sea, the natives go sealing at the edge of the land ice."[112] Such ice-edge hunting is carried on as long as there is water present which, in some localities, is throughout the winter. In certain places, as off Point Barrow, the pack ice moving in toward shore usually causes the formation of small open pools to which the seals resort. According to Murdoch, the men in north Alaska go out in search of these holes between the hummocks. This method is followed throughout the winter where open holes exist.[113] As the ice pack is not consolidated, especially early in fall, there is danger of being caught on a drift moving out from shore. As a result the Eskimos have to ". . . watch the state of the weather; for if a sudden gale blowing from the land should arise, the ice is liable to break, and to be carried into the sea."[114]

Often these holes will remain for some period of time such that those species that do not maintain breathing holes become trapped as the last of the holes begin to freeze over. Then

> . . . the seal climbs up on the ice and begins to creep towards the sea. They sometimes mistake the woods for open water, get lost in the woods. . . . Sometimes a whole herd of seal will come up in the last open hole: in Hopedale some years ago about twenty large Greenland seal were taken with an axe out of a single ice-hole.[115]

As these water holes often provide concentrations of seals, they are visited as long as they last. The Eskimos usually wait on the side of the hole toward which the current is moving so that when a seal is shot it will be carried to the hunter. However, the most frequent method of retrieving seals which have been shot in the water is to use a line with hooks on it which is thrown at the seal until it is snared and can be pulled in. Ice itself is frequently used. Boas writes that a ". . . hunter jumps upon a small cake, which he pushes on with his spear until he is near the body of the animal, and then drags it upon the land floe with the harpoon line."[116]

The most productive ice-edge hunting occurs in the spring. In the Bering Strait area it begins as early as March, in north Greenland and Baffin Island in June or July. This hunting may proceed in several ways but the general method is for the hunter to conceal himself on the ice edge close to the water from which vantage point he spears or shoots the seals as they swim by.[117] Some hunters prefer to walk along the edge of the ice looking for seals, which is much more pleasant than waiting.[118]

A very specialized type of tidal-crack sealing is practiced at Tuat on Lord Mayor Bay by one of the Netsilik groups. It is carried on inside a snow hut which they build over a tidal crack. As there must be darkness inside the hut, very thich snow blocks are used and the entrance is covered with several layers of skins. The part of the crack in the ice that runs through the hut is covered with a piece of ice in which a breathing hole has been cut by the hunter. Seals, in moving along the lead, are attracted to this artificial breathing hole and are harpooned just as in winter. The hunter, however, must remove the harpooned seal rapidly from the lead for, if he wants to use this location again, he cannot let it become soiled by the blood of the seals he captures.[119] This method of sealing is valuable, especially in late spring, and can be used until the snow becomes soft. As the snowhouse protects the hunter from the elements, it is one of the most pleasant methods of hunting seals.

Kayak Hunting. As summer approaches and the ice continues to break up, ice-edge hunting becomes increasingly dangerous. During this period a transition from ice hunting to kayak hunting takes place. As seals frequently come out of the water to bask on ice floes, the Eskimo

Birket-Smith, "The Greenlanders of the present day," p. 126.
Stefansson, "'Living off the country' as a method of arctic exploration," *Geographical Review*, VII, no. 5 (1919), p. 302.
Boas, *The Central Eskimo*, p. 498.
Murdoch, *op. cit.*, p. 269.
Boas, "A year among the Eskimo," *Journal of the American Geographical Society*, XIX (1887), p. 388.
Turner, *op. cit.*, p. 495.

Boas, *The Central Eskimo*, p. 498.
Nelson, *op. cit.*, p. 128.
Manning, *op. cit.*, p. 142.
Rasmussen, "The Netsilik Eskimos, . . ." p. 161.

kayak hunters seek out such floes for more lucrative hunting. The kayaks may be lifted onto a floe which is then used as a raft, being paddled to those floes on which seals are sleeping. In such a case the kayak is the means of getting to a more workable platform.

For many groups, however, ice serves only the purpose of acting as a new shore from which to launch the kayaks. In western Alaska kayaks at the ice-edge are used as early as February.[120] It is only in southern Greenland and the Aleutians that they are used throughout the year. It is in these localities that ice may be considered more of a hindrance to sealing than an asset.

Other Sea Mammals

Walrus Hunting. Walrus hunting is, in many ways, similar to seal hunting, with the harpoon and the gun as the main weapons. These animals are hunted under several conditions: in the open water, at leads, and on the ice. They are generally hunted in the summer, especially late summer, although some Eskimos are able to hunt them in winter and spring as well.

During the summer walrus-hunts, the most important of the year, boats are necessary, although they may be of secondary importance. During this season, walruses sleep on floating ice cakes, and the actual harpooning is frequently from the ice floes rather than boats.[121] In Alaska, in contrast, the walrus is usually shot from umiaks. They are then towed to the nearest cake of ice where they are butchered.[122]

Walruses are also hunted at tidal cracks or leads. Such hunting may be engaged in throughout the winter at such places as Smith Sound, Frobisher Bay, and around Iglulik where certain locations do not freeze.[123] Occasionally the walrus, like other sea mammals, will be trapped by the ice. Kane writes that such a situation is quite important in the economy of the Smith Sound Eskimos who scour the floes with their dogs in search of stranded walruses.[124]

The walrus may be hunted over the ice in yet another fashion, for, although it does not maintain a breathing hole, it can live under the ice as long as the ice is no thicker than the walrus can break with an upward bump of its head. The Eskimos are able to harpoon the walrus as it breaks through the ice without much difficulty, for the walrus can break through ice which is thick enough to hold a man.[125]

After a walrus has been harpooned, the big task of landing it remains. This involves two operations; that of tiring the walrus so that it can be brought to the floe edge and then of hauling it up on the ice. Among some groups, after the walrus has been harpooned, two men work together to hold the line.[126] Even in such a case the ice is used as an aid. The line is fastened by wrapping it around a spear which has been sunk into the ice. The ". . . hunter will often try to hold the walrus by bracing his feet with all his strength against a frozen block of ice."[127] The line, however, may be cut by the edge of the ice in which case the walrus escapes. At other times the edge of the ice floes breaks off dumping hunter and equipment into the water.[128]

The walrus is so heavy (a ton or so) that hunters use special tackle in order to haul one up on the ice. Mathiassen has described one such procedure as follows:

> . . . the line is fastened in a hole cut through the nose of the walrus, then passes round the ice-hunting harpoon shaft which has been stuck into the ice, back again and through a loop formed of a piece of the breast hide and again back in the line on which all the hunters haul. . . . If it is on new ice, thongs are fastened to the fore flippers and these are drawn out to the sides, thus making the bearing surface wider, whereby the ice can stand the weight better.[129]

In some instances, instead of using the harpoon shaft as one end of the pulley arrangement, two converging holes are cut in the ice through which a line is then passed making an effective pulley.[130]

Whaling. Whaling reached its highest development among the Alaskan Eskimos for whom whales furnished a large percentage of the food supply. Its importance is indicated by Hadley, as follows:

> At every cape and headland, from Bering Sea to Point Barrow, and more especially at the latter

[120] Steinert, *op. cit.*, p. 82.
[121] Boas, *The Central Eskimo*, p. 497.
[122] Murdoch, *op. cit.*, p. 272. Weyer, *op. cit.*, writes that the ". . . Alaskan Eskimos have a taboo that walruses must always be hauled up on the ice to be cut up and that this must not be done in the boat." p. 367.
[123] Boas, *The Central Eskimo*, p. 461.
[124] *Op. cit.*, p. 132.
[125] Mathiassen, *op. cit.*, p. 48.
[126] *Idem.*
[127] *Idem.*
[128] Boas, *The Central Eskimo*, p. 499.
[129] *Op. cit.*, p. 49.
[130] Birket-Smith, "The Caribou Eskimos, . . . I. Descriptive part," p. 129.

> and Point Hope, the locations of the largest villages, the passing of the dark days of winter marked the Eskimos' preparations for the great devil dance, the invariable prelude to the spring whale hunt.[131]

Most whales must be taken in the open water. Therefore, the relationship between ice and occupation is not as close in whaling as that which evolved in seal hunting, or even, for that matter, walrus hunting. Ice, nevertheless, is important in whaling, an importance that, in the case of Alaska, varies in degree with the season. During the early whaling season ice is of definite advantage to whaling while during the late season it hinders the whaling operation. The early season is by far the most important of the two.[132]

When the time comes at Point Barrow for whaling to begin

> . . . exploring parties are out every day examining the state of the ice to ascertain when the pack is likely to break away from the landfloe, and also to find the best path for the umiaks through the hummock.[133]

These paths, which often are marked during the winter by seal hunters, are improved by the Eskimos in their leisure time. They widen and smooth them by ". . . knocking off projecting points of ice with picks and whale spades, and filling up the worst of the irregularities."[134]

Ice, serving as a base of operations, is an important adjunct to the whaling at this season. "As soon as the lead opens, and sometimes before when the prospect looks promising, the boats are taken out to the edge of the land floe . . ." on sledges.[135] At the edge of the land floe preparations are made for launching the umiaks as well as waiting for the whales. A small ramp is cut to the water down which to slide the boat and snow blocks about two and one-half feet high are set up along the edge of the ice. These snow blocks serve two purposes; they act as a windbreak and, more important, they ". . . obliterate unnatural shadows and silhouettes of boats and hunters."[136] The time spent at the ice edge is a busy one, for as long as there is open water, the crews are continually looking for whales.

Whales, like walruses, have to be handled with special equipment. Hadley describes one of the techniques as follows:

> A slip or runway had to be cut to the edge of the water and the whale was secured by walrus hide lines passed round a sort of windlass constructed from a rounded cake of ice and a piece of driftwood. Then the creature could be heaved up. . . . If the edge of the ice were very rough and uneven a somewhat different method would be employed; the whale would be rolled alongside the ice and rolling and cutting be substituted for heaving and cutting.[137]

Large whales are always hunted from boats. It is only the smaller narwhals and belugas that are occasionally hunted from the ice edge. These two are quite abundant in many parts of the Arctic and of great importance to some Eskimo groups. Savssat hunting in west Greenland is the most lucrative of all ice-edge hunting, for when narwhals are trapped by the ice great numbers can be taken with relative ease from the edge of an ice hole.[138]

[131] "Whaling off the Alaskan Coast," *Bulletin American Geographical Society*, XLVII (1915), 914. This ceremony was only a part of the preparations; equipment and crews were also readied for the spring hunt.

[132] The difference in the importance of the two whaling seasons cannot be explained solely by ice conditions. Sonnenfeld, *op. cit.*, for example, has suggested that the need for food is not as great in the fall as in spring because the storehouses are stocked from the early whaling season, p. 85.

[133] Murdoch, *op. cit.*, p. 273.

[134] *Idem.* In the past, if the land floe happened to be particularly rough, the hunters would move to another location along the coast where the floe was smoother.

[135] Murdoch, *op. cit.*, p. 274.

[136] Sonnenfeld, *op. cit.*, p. 88. Birket-Smith in "The Greenlanders of the present day," reports this same technique for the Ammassalingmuit. They also use snow blocks when hunting seals, walrus, narwhal, and beluga. For camouflage they also paint their kayaks white, p. 127.

[137] *Op. cit.*, p. 916.

[138] Porsild, *op. cit.*, p. 216.

Food Production: Eskimo Hunters and other Food Sources

There were only three sections of the Eskimo Arctic in aboriginal times where the natives had a dominant food source of something other than the sea mammals. These areas are the Barren Grounds west of Hudson Bay, interior Alaska, and the coast of Alaska around the mouth of the Yukon River. Of these three groups, the first two had as their main subsistence item the caribou, the last, fish. In all other areas sea mammals dominated, at least, most of the time.

Among all groups of Eskimos, however, foods other than the dominant one were more or less important. Some had additional sources of food throughout most of the year; others had more of a seasonal variety, with some food types almost or completely replacing the dominant one for various periods of time.

The methods used in obtaining these other foods (whether they be mammal, bird, or fish) vary greatly with the conditions of snow and ice. Some of the techniques which have been developed utilize the various properties of snow and ice in their successful operation.

Caribou

Eskimo Utilization of Caribou. The caribou, like the seal, serves a multitude of uses. Although never domesticated in the New World, its flesh is the most desired of foods to many of the Eskimos, and its skin, if acquired at the right season of the year, is the best of clothing material for most arctic conditions. The quality of caribou varies with the season, generally being best from the standpoint of both food and clothing from mid-July to about mid-September.[139] Autumn hunts, thus, have become the most important of the year; but, nevertheless, caribou are also hunted during the other seasons.

One group of Eskimos, more than all others, has concentrated its efforts on caribou hunting. This concentration was carried to such an extent that the Fifth Thule Expedition members labeled them the "Caribou Eskimos."[140] To these people ". . . the caribou occupies at least the same position as the seal and the walrus do to their kinsmen. . . ."[141] Although the Caribou Eskimos depend upon caribou for more of their sustenance than any other group of Eskimos, it is of great importance to most other groups as well. Among the Iglulik Eskimos, for example, "Caribou hunting is the favorite occupation . . . [and] is pursued in all seasons wherever there is an opportunity."[142] Basically the same condition is noted for the Alaskan Eskimos: "Nearly every day in the autumn and winter, when the weather is not stormy, one or more natives are out looking for reindeer, . . ."[143]

Hunting Methods. Sonnefeld recognizes four

> . . . ways in which Eskimo hunt the caribou: by herding the animals into a corral, river, lake, or simply hidden gap where others are waiting for the kill; by the use of snares; by stalking; and by the use of snow pits or traps.[144]

Of these methods the most important from the standpoint of its relationship to snow is the last, the only method that cannot be practiced throughout the year. Snow and ice, while not necessarily important in the function of the first three methods, may, nonetheless, have a great influence on their successful operation.

Snow Pits and Traps. The one basic requirement, other than the presence of caribou, for the use of snow pits or traps in caribou hunting is an adequate snow cover in, or from, which to construct the trap. The construction varies with the thickness of this cover.

One type of pitfall constructed when the snow is not very deep has been described by Hanbury as follows:

> In a deep snow-drift they dig an oblong pit about six feet deep, and then with blocks of snow build up walls about four feet high, so that for the deer there is a fall of about ten feet. An easy slope leads up to the very thin roof of snow, and the structure has a natural appearance. . . . Deer, however, must be numerous for a fair chance of success, and the pitfalls must be closely watched; for, as soon as a beast falls into a pit, he commences to fight and worry, and if he dies from exhaustion, as he soon does, the flesh is almost uneatable.[145]

A somewhat less elaborate procedure in thin snow is to construct a narrow, gradually deepening path in the snow which ". . . ends in a small pitfall into which the caribou tumbles. It must suit the size of the caribou; i.e., it must not be so big that the caribou can turn around, . . ."[146]

If the snow is somewhat deeper, a pit sufficiently deep can be dug without resorting to the use of snow blocks. These pits are frequently covered with twigs and a thin layer of moss.[147]

The Alaskan Eskimos, instead of digging an oblong hole, dig a round hole which is

[139] Weyer, *op. cit.*, p. 54.
[140] Birket-Smith, "The Caribou Eskimos. . . . I. Descriptive part," p. 9.
[141] *Idem.*
[142] Mathiassen, *op. cit.*, p. 53.

[143] Murdoch, *op. cit.*, p. 264.
[144] *Op. cit.*, p. 6.
[145] *Op. cit.*, p. 114.
[146] Rasmussen, "Observations on the intellectual culture of the Caribou Eskimos," p. 41.
[147] Birket-Smith, "The Caribou Eskimos. . . . I. Descriptive part,"

> . . . about 5 feet in diameter and 5 to 6 feet deep, and is brought up to within 2 or 3 inches of the surface, where there is only a small hole, through which the snow was removed. This is carefully closed with a thin slab of snow and baited by strewing reindeer moss and bunches of grass over the thin surface through which the deer breaks as soon as he steps on it. The natives say that they sometimes get two deer at once.[148]

All groups use a bait with their pitfalls, a bait generally made with urine, the salt of which attracts caribou. The body of the bait might be snow, but more commonly it is reindeer moss. Both are soaked in urine prior to using.[149] Boas reported that among the Central Eskimo, salt-water ice is placed upon the trap to lure the deer.[150] During early fall, before the entire countryside is covered with snow, a lure made out of snow itself is frequently used. Apparently caribou have a natural curiosity for white, and so the hunter builds a snow cairn near which he has constructed pitfalls.[151]

The importance of the pitfall varied greatly among the Eskimos and has declined in use since the introduction of the rifle. Murdoch has written that fall caribou hunting among the Point Barrow Eskimos is a new custom, for it was

> . . . probably not worth while to go out after deer at seasons when there was not enough snow for digging pitfalls, for they depended chiefly on these for the capture of the reindeer before the introduction of fire-arms.[152]

Although this type of caribou hunting has decreased in importance, it has not completely disappeared for it is still occasionally used by the Eskimos, including those in northern Alaska, to supplement their food supply.

Herding and Driving Techniques. The Eskimos devised many methods of driving or enticing caribou to predetermined locations. The white cairn has been mentioned in connection with pitfalls and is used generally in the attempt to trap one animal at a time. Usually, when the driving or herding method is to be attempted, many animals are involved. These animals are generally driven into the water where they can be killed from kayaks. The efficiency of kayaks is affected by the amount of ice in the water which, therefore, has a bearing on the effectiveness of this type of caribou hunting. Among the Central Eskimo, for example, this type of hunting " . . . is especially profitable in the autumn and more favourable than in the spring, since in autumn no ice floes endanger the kayaks."[153] However, later in the season, when ice begins to form but before it becomes firm the Eskimos frighten the caribou into running out onto thin ice where they break through and are easily killed.[154]

Stalking. Snow probably brings more disadvantages than advantages for the stalking method of hunting. The advantage of easier trail-following with a snow cover is offset by the increased noise level. In calm weather

> . . . footsteps can be heard far away; if the terrain is flat into the bargain, hunting may be almost impossible, long periods of this kind of weather will often bring the Eskimos to the verge of starvation. Caribou hunting is easiest in slightly misty weather, preferably with a little wind and snowfall, . . .[155]

With drifting snow, caribou tend to stand quietly and are relatively easy to approach and kill.[156] When, on the other hand, drifting of snow decreases the visibility too much, hunting becomes impossible.

The disadvantage of noise resulting from a snow cover probably, at least in part, accounts for the technique used in clear weather by the Eskimos of the Melville Peninsula. When they came upon a herd of caribou they would give chase without any idea of stalking. The caribou would run a short distance and then stop to watch the approaching sled. When the sled got within about 100 yards of the caribou they would run again. The Eskimo hunters would shoot at the animals occasionally, hoping for a hit.[157]

Other Caribou Hunting Practices in which Snow is Important. Some groups of the Copper Eskimos used to go inland from the Hope Bay area early in spring when there was still snow on the ground. Instead of constructing pits they often hunted the caribou ". . . from hides that were built up of snow in the days when they only had

[148] Murdoch, *op. cit.*, p. 268.
[149] Birket-Smith, *loc. cit.*
[150] *The Central Eskimo*, p. 509.
[151] Birket-Smith, *loc. cit.*
[152] *Op. cit.*, p. 266.

[153] Steinert, *op. cit.*, p. 31.
[154] Boas, *The Central Eskimo*, p. 502.
[155] Mathiassen, *op. cit.*, p. 54. The increasing audibility of sound with cold hinders hunting in yet another way. Schwatka writes that the ". . . twang of a bow string travels faster than the arrow . . ." and frightens the caribou. Rifle shots, however, sound so much like ice cracking that little attention is paid to them. *Nimrod in the North* (New York: Cassell & Co., 1885), p. 71.
[156] Birket-Smith, "The Caribou Eskimos, . . . I. Descriptive part," p. 107.
[157] Manning, *op. cit.*, p. 146.

bow and arrow."[158] As these groups spent most of the summer and autumn in caribou hunting, they would go inland great distances traveling up on the last snows of spring and not returning to the coast until the winter.[159]

Poleward of the tree line, snow is seldom deep enough to be a real hindrance to caribou. Such a condition does not hold, however, for the forested areas to the south where not only the Indians but also the Labrador Eskimos take advantage of deep snow. By using snowshoes they are able, with relative ease, to overtake the deer which sink into the snow.[160]

Other Land Animals

As in the case of the caribou, snow and ice are important determinants in the frequency and distribution of the other land animals and have a bearing on the techniques used in hunting them. Many of the techniques used in caribou hunting are used in hunting these other animals, although often varied to conform to the traits of particular animals.

Musk Ox Hunting. The hunting of the musk ox was made rather easy for man by the defensive methods used by this animal. This defense is to meet the attack "head on," a system that works well with all enemies except man with weapons. In the hunting of the musk ox no special techniques evolved. The big problem was locating a herd. Most frequently these were happened upon by the Eskimos when traveling. Snow is of little significance in this type of hunting except that it makes the trails somewhat easier to follow,[161] and, because of the color of the musk ox, it causes them to stand out against the white background. During the snow-free season, the opposite condition prevails for then the musk ox blends in well with the tundra.

When actually out hunting musk ox, dogs are used to trail the animals and to bring them to bay where they can be killed with spears, bow and arrows, or, in modern times, guns.

Polar Bear Hunting. The polar bear has been hunted extensively by some groups of Eskimos since long before the introduction of the gun. This animal is still quite important to some peoples because of its skin and meat. In earlier times it appears to have also provided a diversion that was enjoyed by the hunter. Steinert writes that "Toward the end of the winter, when it becomes light again, there begins the hunting of the polar bear, the high point in the life of the Polar Eskimo."[162]

Many polar bears are taken as they come into camps or villages—especially toward the end of winter—hunting for food. Organized hunts, however, are engaged in and nearly always make use of dogs.[163] The polar bear is a much more difficult animal to find and to kill than is the musk ox. Unlike the musk ox, which remains more or less stationary and in groups, polar bears roam over wide areas, usually alone. Normally, unless in a den, it will be found on the ice among the hummocks where it blends in with its environment. The bear's cunning is often praised, for it utilizes the natural environment to the utmost. Snow and ice characteristics are taken advantage of, not only in stalking or evading man, but more especially in seeking out and stalking the seal, its main food item. Such factors make the hunting of polar bears a somewhat dangerous occupation, especially prior to the introduction of high-powered rifles. Dogs are used to track a bear and to bring it to bay, where it is killed by the hunters.

A somewhat safer method of hunting the bear is also used. Female bears dig dens in the drifted snow, generally on the southern side of a hummock or hill, where they spend the winter and where they have their cubs. These bear "igloos" are located by Eskimo hunters with the use of dogs. Once a den is located, the hunter probes into it with his spear to determine if it is still occupied. If it is, the hunter then cuts into the den and as the bear awakens and comes out it is killed.[164] This type of hunting is by far the most important type of polar-bear hunting among some groups. At Pelly Bay, for example, over a four year period from 1952 to 1956, a total of eighty-one adult bears was taken, of which sixty-two were killed in dens. More than four-fifths of the total were females, most with cubs.[165]

158 Rasmussen, "Intellectual culture of the Copper Eskimos," p. 78.

159 *Ibid.*, p. 77. These trips inland were not solely for the pursuit of caribou, but included some trading and wood gathering as well.

160 Tanner, *op. cit.*, p. 621. Snowshoes, generally not used by Eskimos, are also reported as being used in caribou hunting by the Point Barrow Eskimos. Murdoch, *op. cit.*, p. 263.

161 The importance of snow in trailing a musk ox should not be overemphasized. Grazing patterns are such that they normally move only short distances over an entire season.

162 *Op. cit.*, p. 80.

163 Boas, *The Central Eskimo*, p. 509.

164 G. Mary Rousselière, "A bear hunt on Simpson Peninsula," *Eskimo*, XLV (1957), p. 18.

165 F. Van de Velde, "Nanuk," *Eskimo*, XLV (1957), p. 13.

Techniques Used in Hunting Small Animals. The small animals are generally taken today by steel traps or else they are shot with guns. These methods rapidly replaced earlier techniques as soon as they were introduced.

There are three basic ways in which small animals are hunted. The first is the gun, which is used for hunting hares, foxes and wolves. The second involves some method of imprisoning the animal such as with a trap, snare, or net. These devices hold the animal for varying lengths of time. Some are watched by the hunter so that the trapped animal can be removed at once; others are visited periodically. The third technique includes the various methods in which the animals kill themselves with such weapons as the famous (or infamous) "wolf-killers."

Of the various methods used to capture or imprison land animals, traps and pitfalls involve the use of snow and/or ice more than any of the others. One of the most widely used types of traps is the so-called "tower trap." In aboriginal days this trap generally was made of stone and was a more or less permanent structure, being used year after year. Its use was quite extensive although apparently it was not used west of the Mackenzie River.[166]

Tower traps constructed of snow were used in arctic Canada by the Eskimos but were unknown in Greenland. There were several variations in the construction of such traps. The Cumberland Eskimos formerly made their traps high enough for a man to stand in. In such a trap bait was hung beneath the funnel-shaped hole which had been left in the top of the structure. it was through this hole that the fox had to jump in order to get to the bait, but once inside it was unable to climb out.[167] There are other ways in which the tops of these traps can be arranged. The opening may be partially covered with a piece of whalebone ". . . which, bending beneath their weight, lets them into prison, and then resumes its former position: thus a great number of them are sometimes caught in a night."[168] Sometimes the top of the snowhouse is made of thin ice so that when the animal climbs on top it will break through.[169] Ice is utilized also by being placed around the opening in the top of the trap to make it slippery.

Such tower traps are unknown in Alaska. There the Eskimos use pitfalls similar to those used for caribou. Pitfalls are found throughout the Arctic although their use is restricted to certain types of animals in various localities. In west Greenland they are used for smaller animals such as the fox but not for caribou.

Snares of various kinds are used by the Eskimos throughout the Arctic. Not infrequently snow is used in disguising various parts of the snare. Most snares are rather simple as is illustrated by an arrangement the Netsilik frequently use. They place a

> . . . number of blocks of snow . . . side by side about like a wind screen. They form a kind of wall, in the middle of which an opening is made, and in it is a small snare especially intended for hares. The hare runs along by the wall and, when it comes to the opening, will as a rule try to slip through it but becomes entangled in the snare.[170]

Nets, like snares, are known in various forms throughout the Arctic. Generally snow or ice is used only incidentally, for hiding either the net or the hunter. Snowhouses are sometimes built in which the hunter hides until the animal is caught in the net.[171]

Some groups kill small game with a deadfall. This device functions by dropping a weight on any animal that trips a trigger mechanism as it attempts to get some bait that has been properly placed. The Copper Eskimos make a deadfall arrangement in which ". . . a large heavy piece of ice is set up on edge, when the animal snatches at the bait hanging below, the block falls on it."[172] More complicated deadfalls involve the construction of a small snowhouse with an entrance on one side through which the animal must go to get the bait. Once inside the animal is killed by a dropping weight.

Very few small animals are taken today with methods other than the steel trap. When these traps were introduced among the Eskimos, they were frequently incorporated into aboriginal methods of hunting. The Alaskan Eskimos, according to Murdoch, used the steel trap instead

[166] Birket Smith, "The Caribou Eskimos . . . II. Analytical part," p. 25.
[167] L. Kumlien, "Contributions to the natural history of arctic America, made in connection with the Howgate expedition, 1877-78," *Bulletin, United States National Museum*, no. 15 (1879), p. 41.
[168] Lyon, *op. cit.*, p. 339.
[169] Mathiassen, *op. cit.*, p. 63.

[170] Rasmussen, "The Netsilik Eskimos . . . ," p. 189.
[171] Sonnenfeld, *op. cit.*, p. 154.
[172] Rasmussen, "Intellectual culture of the Copper Eskimos," p. 112.

of the deadfall at the entrance to a snowhouse trap.[173]

Snow is usually used to hide the trap from the animals. Normally, after fastening the trap in the permafrost by a chain, a

> . . . block of snow 1½ feet square and some 6 inches high is cut, and a hollow made in the centre for the trap. Then a further block of snow is placed over it and scraped thin enough to be broken by the Fox's weight.[174]

Some hunters, instead of using a special block of snow, simply scoop out a hole in the snow in which the trap is placed. It is then covered with a snow topping.

The above hunting techniques have been and are being used successfully. They are not, however, the ones that have been emphasized in the literature. The simple and ingenious techniques which depend on cold rather than snow and ice and commonly labeled "wolf-killers" have received the greatest attention. These weapons include the freezing of some sharp object (s) in a chunk of blubber which is swallowed by the wolf. Today glass and razor blades are used.[175] Formerly, baleen was used by most of the Eskimos, although those central tribes who did not have access to whales substituted musk-ox horn.[176]

Bird Hunting

Bird hunting techniques used by the Eskimos include: (1) traps and snares; (2) nets; (3) weapons of various sorts; and (4) gathering. All of these methods are still used today, although the shotgun became the most important weapon in bird hunting.[177] Gathering includes the driving of moulting geese to camp where they can be slaughtered and the taking of birds at a savssat. The savssat-gathering depends on ice conditions.

Bird traps and snares are of many varieties in the Arctic, many of them similar to those used on the smaller animals. Some bird traps utilize snow and ice, as did those described above. The most elaborate of the bird traps is the snowhouse type used by the Central Eskimos and the Eskimos of east Greenland. It is generally used along the shore and seems to be restricted to the various gulls. Mathiassen writes that a snowhouse is built

> . . . just large enough to contain a man; at the top is a small opening, wide enough for him to put his hand through and seize the gull by the legs; the gull is attracted by meat laid on the roof.[178]

Boas adds that in some places the hole in the roof is covered with a block of translucent ice so thin that the hunter can push his hand through it. In this case the bait, instead of being scattered on the roof around the hole or on the snow around the trap, can be placed on the thin ice covering the hole.[179]

The most important method of taking birds that the Eskimos use, other than with guns at the present time, is with nets. This method is probably more important among the Polar Eskimos than with any other group. They use long-handled "butterfly" nets to capture birds from the nesting cliffs in northwestern Greenland. Snow and ice are handicaps to such hunting in that they increase the danger of climbing the cliffs where the nesting birds are found.

Snow and ice are, however, used to advantage by some groups in the netting of birds. Nelson has written that ptarmigan are netted by using a decoy made of snow in the form of a bird.[180] After the net has been placed around the decoy the hunter, by imitating the call of a male ptarmigan, causes the ptarmigans in the vicinity to think their territory has been invaded. They then attack the decoy in the net and become trapped.

A variety of weapons, including bolas, slings, darts, and guns, is used by the Eskimos. Such weapons were employed especially during the spring and fall migrations when birds fly over in great numbers.

Although little concealment is attempted for general hunts, hideouts are used at strategic points along the coasts where ducks and geese generally cross. Blinds are often made of snow blocks.[181]

The only direct use of snow or ice in bird hunting with weapons is where it is used as a projectile. Birket-Smith has reported that the Central Eskimos often substitute lumps of ice for stones when using their slings.[182]

[173] *Op. cit.*, p. 260.
[174] Manning, *op. cit.*, p. 147.
[175] *Idem.*
[176] Birket-Smith, "Ethnographical collections from the Northwest Passage," p. 57.
[177] Mathiassen, *op. cit.*, p. 64.

[178] *Op. cit.*, p. 64.
[179] *The Central Eskimo*, p. 512.
[180] *Op. cit.*, p. 132.
[181] Sonnenfeld, *op. cit.*, p. 402.
[182] "The Caribou Eskimos, I. Descriptive part," p. 116.

Fishing

Rostlund, in his exhaustive study on aboriginal fishing in North America, placed all of the Eskimo groups, save two, in his rank 2, which includes all groups for whom ". . . fish was a staple food but no more important than game or plants, . . ."[183] The one major exception to this grouping includes the inland Eskimos along the Kuskokwim, Noatak, and Colville rivers whom he places in rank 1, those for whom ". . fish was the most important staple in the annual food economy."[184] The other possible exception to the relatively important position of fishing among Eskimos is, in Rostlund's table, listed as the Polar Eskimos whom he has shown as rank 2 or 3 for ". . the men rarely and the women only infrequently devote time to fishing . . ."[185] Although fish is generally of only secondary importance in the total food supply, it nevertheless is ". . . in many places an indispensable addition to the food supply."[186] Indeed, at certain times of the year, fish may be the only food available to some groups.

Fishing may be carried on at all seasons, but with more or less emphasis depending mainly upon the other seasonal occupations and the season of greatest fish abundance and need. In Greenland, for example,

> Everything else failing, the Greenlanders, as a last resource, take to fishing the lean and bony sea scorpion and to gathering mussels and edible seaweeds, but this is more or less considered starvation fare.[187]

In Labrador, fishing is done in what might be considered as the in-between season, that is, during March when seals are rare and caribou have not yet appeared.[188] Among the Caribou Eskimos, with whom fish is next to caribou in importance as a food item, fishing is engaged in at all times of the year. The most important fishing season for most of the Eskimos, however, is summer, corresponding with the time of year when, for most groups, sealing is least important. Fish, at that season, are generally available in most of the waters of the Arctic although they tend to be concentrated in certain localities at both the beginning and the end of the season.

Fishing techniques among the Eskimos include the use of various kinds of leisters, spears, harpoons, bow and arrow, hooks, nets, snares, traps, and weirs. All of these, except the weir and bow and arrow, are used during the winter as well as at the other seasons of the year. Most Eskimo fishermen formerly depended on the hook in winter fishing, although today the net has increased greatly in importance and is probably more important, even in winter, than the hook.

Summer Fishing. Ice is normally a disadvantage in summer fishing. The weir requires running shallow water for its successful operation and is limited to summer usage. The bow and arrow[189] is limited to ice-free or nearly ice-free water bodies. Some types of netting are handicapped by ice. Seines, for example, cannot be used ". . . in bays and coves as long as there is risk of them being carried away by drift ice."[190] Apparently the only use to which ice is placed in the summer is as a base of operations. The Iglulik Eskimos for example, fish ". . . from drift-ice floes near the shore . . ."[191]

Winter Fishing. Although the same equipment is used for fishing in winter as in summer, the method of use often differs. Early in the cold season, as the ice is forming, fishing is practiced along the leads in the ice where all techniques may be employed. As the ice cover becomes complete, lead fishing must give way to fishing through holes cut in the ice. Some type of ice-hole fishing is by far the most important type of winter fishing and is apparently engaged in by all Eskimo groups. There are great variations in its importance and in the techniques used from one group to another.

Fishing Hole Location and Construction. The location of the hole to be dug through the ice has to be carefully considered. If the fishing hole is to be made in river ice, a section of the river that has a large pool beneath the ice must be found. De Poncins writes that one method the

[183] *Freshwater fish and fishing in native North America* (Berkeley: Univ. of Calif. Publ. in Geography, 1952), p. 173.

[184] *Idem.* This ranking, not only by Rostlund but also by Driver and Massey, *op. cit.*, appears to have been influenced by a statement made by Birket-Smith in "The Caribou Eskimos . . . I. Descriptive part," that the Kuskokwim tribes ". . . seem to be a specialized fisher people . . ." p. 35. Kroeber, *op. cit.*, in Table 2 on "Regional Variety of Eskimo Economic Culture," lists for the Yukon Kuskokwim Deltas: "Shallow shore water, no whaling, little sealing, prime dependence on salmon, supplemented by other fish and birds, no reindeer." p. 24.

[185] Ekblaw as quoted by Rostlund, *op. cit.*, p. 201.

[186] Birket-Smith, *The Eskimos*, p. 94.

[187] Birket-Smith, "The Greenlanders of the present day," p. 106.

[188] Steinett, *op. cit.*, p. 54.

[189] Apparently the only Eskimos who used the bow and arrow in fishing are in northwest Alaska. Nelson, *op. cit.*, p. 155.

[190] Birket-Smith, "The Caribou Eskimos . . . I. Descriptive part," p. 121.

[191] Mathiassen, *op. cit.*, p. 70.

Eskimos use to insure such conditions, before expending the energy needed to chisel a hole, is, after clearing the snow away from the ice, to kneel down and look through the ice into the water below.[192] This procedure also serves as a check on the availability of fish below. In estuaries and lakes, as long as they are not frozen to the bottom, little selection is needed. Ice holes vary greatly in size, depending mainly on ice thickness—the thicker the ice the larger the hole. The main tools used in digging such ice holes have been described above in connection with water procurement.[193]

Techniques Used in Fishing Through the Ice. Fishing through holes in the ice is conducted in three basic ways: (1) with leisters, spears, or harpoons; (2) with fishhooks; and (3) with fish nets and traps.

Spearing fish through holes in the ice is practiced only in thin ice, for the thicker the ice the more difficult it is to spear fish as they swim past the hole. Being able to see the fish in this type of fishing is a necessity and various techniques are used to improve visibility. The Back River Eskimos have developed a technique that not only improves visibility but also attracts fish to the hole. Over the fishing hole they construct a snowhouse in which they lie on their stomachs looking down into the water. The snow around the hut is cleared off the ice allowing the light to penetrate the water, which attracts the fish.[194] Decoys are frequently used to attract fish and are usually jiggled in the water with one hand while the spear is held poised with the other.

A specialized type of spear fishing, called "nest-fishing" by Mathiassen, is engaged in by the Central Eskimos.[195] In October the female salmon lay their eggs among the stones on the bottom of the river under the ice. The fishermen locate these nests, which are guarded by the females, and watch through holes in the ice until the males come to fertilize the eggs. The males alone are speared, generally with a salmon spear, the handle of which has been lengthened so that it will reach the bottom of the stream. Nest fishing among the Iglulik is often engaged in by two men. ". . . one of them lying on watch at the hole while the other directs the spear according to the signs from the man at the hole; . . ."[196]

Spears are often modified as in the case of that used in nest-fishing, but not uncommonly, instead of a spear or leister, some fishermen use a harpoon. In west Greenland winter shark fishing at ice holes is much like floe-edge sealing and depends on the harpoon.[197]

Among many groups the fishhook is the most common fishing implement, although its importance is gradually giving way to the net. Hooks among the Eskimos are quite varied in form but are used in two main ways: as baited hooks, or, more frequently, as jigs. Both techniques are used through holes in the ice, and both make fishing in deep water possible. For the successful operation of leister or spear, in contrast, the fish have to be near the surface. During the summer deep-sea fishing is limited practically to the Eskimos of Alaska, Greenland, and Labrador, but during winter most of the other groups take advantage of the ice to reach deeper water both in lakes and at sea. It is only in this deep water that fishing can be carried on during the winter in some locations. Off Point Barrow tom-cod fishing is practiced up to a distance of several miles from the shore wherever the fishermen can find a favorable site—generally in the lee of some hummock.[198]

Fishing with hook and line through the ice is often carried on in very cold weather. Ice that forms in the ice hole must be removed periodically, which in practice has become an integral part of the fishing operation.[199] The dipper for removing the ice crystals as they form is usually held in the left hand and the fish line in the right.

Because of the cold, windbreaks are usually made around the fishing holes. They are of many varieties and may be more or less permanent. The most common windbreaks are made of snow blocks piled to the windward of the hole. However, in the Bering Strait area a framework of wood over which grass mats are draped is frequently used.[200]

[192] *Op. cit.*, p. 66.
[193] *Supra*, p. 131.
[194] Birket-Smith, "The Caribou Eskimos. . . . I. Descriptive part," p. 124. Birket-Smith writes that Hearne describes the inland Eskimo as fishing from tents pitched on the ice for the same purpose, p. 124. He also writes in *The Eskimos* that this method of fishing was practiced in only two places—the Barren Ground and Colville Delta—by the 1920's because it was ". . . forced into the background by ice fishing with the jig. . . ." p. 96.
[195] *Op. cit.*, p. 69.

[196] *Idem.*
[197] Birket-Smith, "The Greenlanders of the present day," p. 132. The most important shark fishing in Greenland, however, ". . . is done by means of hooks, partly from kayaks and partly from the ice." p. 134.
[198] Murdoch, *op. cit.*, p. 283.
[199] *Idem.*
[200] Nelson, *op. cit.*, p. 176.

Nets as fishing equipment are recent additions among the Eskimos,[201] although they were used in pre-contact times for seals. Since European contact, fishing with nets has been introduced to all areas, although it is not used by all groups during the winter. Among the Caribou Eskimos, who now use nets in summer, ". . . net fishing from the ice is impossible, because the nets cannot be dried in the unheated snow houses."[202]

Two basic types of nets are used for fishing under the ice: dip nets and set or gill nets. The dip net is the less important, being used at only one location as well as can be determined. The Eskimos living along the Yukon River cut holes through the river ice as soon as it becomes sufficiently strong to hold them in the fall and watch for the annual run of lamprey.

> As soon as the first one is seen everybody seizes a dip-net or a stout stick with a short cross-piece at the lower end and throws out as many as possible. When the body of fish have passed, the people run up the river for some distance, cut other holes, and repeat the catch.[203]

A much more common method of net fishing is to set the nets under the ice. It is practiced by the Eskimos throughout the Arctic during the winter and is practiced under lake, river, and sea ice. The general method of setting nets under the ice is by cutting a series of holes in the ice and pushing a pole from one hole to the next thus threading a net through them.

> Care must be taken to see that the net is properly sunk so that as the ice thickens it will not freeze in. A fish net can be, and often is, set out even in mid-winter when the ice is 4-6 feet thick. . . . It is little trouble to open the two end holes to draw the net, especially if they are covered with snow and the net visited regularly.[204]

Fish traps are found in several areas, although they are not common. The Alaskan Eskimos have developed them to the highest degree and apparently are the only Eskimos to set them under the ice.[205]

Nearly all of the fishing of the Eskimos, and especially that at the ice holes, is for the so-called "bony fish." However, as indicated by Birket-Smith, the Eskimos do engage in other types of fishing at times.[206] Shellfish are found along many coasts; however, during winter they are not available because of shore ice. Another type of fishing conducted by the Cape Darby Eskimos in the winter is for crabs. "Their crab lines were fastened to small sticks set in the snow beside the holes in the ice, thus enabling one person to watch several holes."[207]

Vegetable Foods

The land area occupied by the Eskimos contains a flora that in general is quite sparse and contributes, for the most part, only indirectly to the food supply of the aborigine. Most Eskimos do eat some plant food other than the partly fermented and rather sourish contents of caribou stomachs.

Practically all types of plant growth are eaten by some of the Eskimos in times of need. Included are various types of berries, which are quite abundant in season in many parts of the tundra, roots, leaves, mosses, and sea-weeds. The quantity of vegetable food consumed varies greatly from group to group and from season to season. There are some groups, such as the Iglulik, for whom vegetable food is of no consequence.[208] For others, as among the Eskimos around Bering Strait, plant food may amount to as much as five per cent of the diet.[209]

The season in which plant food is gathered, generally late summer, is also the season in which most of it is consumed. Gathering, for the most part, is limited to this season because after the snow falls berries and other plant products will be hidden under the snow. Under certain conditions gathering may be pursued at other times of the year. Ostermann, in writing about the east Greenland Eskimos, notes that at the settlement of Umanaq frequent gales keep the snow blown off the mountain sides so that ". . . berries can be gathered almost throughout the winter season."[210] These Eskimos, during October and November, if hunting is poor, climb the mountain side and eat sorrel, roots, and cranberries.[211] In some localities berries are picked in the spring.

[201] See Rostlund, *op. cit.*, in which he sums up the evidence for the recency of net introduction for purposes of fishing among the Eskimos, p. 85 ff.
[202] Birket-Smith, "The Caribou Eskimos. . . . II. Descriptive part," p. 118.
[203] Nelson, *op. cit.*, p. 190.
[204] Manning, *op. cit.*, p. 146.
[205] Nelson, *op. cit.*, p. 185.

[206] *Supra*, p. 226.
[207] Nelson, *op. cit.*, p. 183.
[208] Mathiassen, *op. cit.*, p. 107.
[209] Weyer, *op. cit.*, p. 53.
[210] "Knud Rasmussen's posthumous notes on the life and doings of the East Greenlanders in olden times," Meddelelser om Grønland, Bd. CIX, nr. 1 (1938), p. 27.
[211] *Ibid.*, p. 47.

after the snow which has covered them all winter has melted, so exposing them.

Snow, although decreasing the chances of finding berries, very often is indicative of improved quality, for many berries are improved through freezing. The crowberry *(Empetrum nigrum)* is such a berry and is the most important plant food of the Greenlander. These berries ". . . are sweetest when they have been exposed to frost, and are therefore mainly collected late in the autumn or in the winter from below the snow."[212]

The Greenlanders use special tools in this type of gathering. They pick the berries with a

> . . . berry scraper, a curved plate of antler, the wings of which are united by a wooden handle, and they are separated from the snow by means of large skin sieves in the shape of bags with perforated bottom.[213]

Apparently no other Eskimo groups have developed the art of berry picking to such a degree. Although they gather berries, they never gather them from under the snow.

Although vegetable food is seldom gathered in winter, many Eskimos do eat it then, for part of that gathered during the fall is frequently stored for winter use. Many items, including roots, berries, and the stomach contents of caribou, are frozen for this purpose.[214] Frequently berries, roots, stems, and leaves are mixed with blubber before being stored for the winter.[215]

[212] Birket-Smith, "The Gre nlanders of the persent day," p. 138.

[213] *Idem.*

[214] Weyer, *op. cit.*, p. 55.

[215] A. E. Porsild, *op. cit.*, p. 19.

Food Production; Non-Eskimos in the Arctic

For the most part, snow and ice have been limiting factors only in the acquisition of food by non-native peoples dwelling in the Arctic; a fact as valid for most explorers as for today's non-native population. Nearly all of the food used by the non-native in the Arctic today is imported. Only occasionally (generally in emergencies) does local food, other than fish, furnish anything more than an incidental item in the diet of the whites in the Arctic.

The Explorers

Those early explorers who wintered in the Arctic, whether by design or not, suffered greatly because of diets deficient in both quantity and quality. Poor quality of food usually resulted in the dreaded scurvy from which the Eskimos, living entirely on locally provided food, rarely suffered.

Nearly all of the early explorers, believing that they could not live off the land (or sea) in the Arctic, did not try to supplement their food supply except for the most obvious and conspicuous of animal and plant forms. None, however, was averse to taking a ptarmigan, musk ox, caribou, or polar bear if the opportunity presented itself. According to most explorers, however, such opportunities were infrequent and were seldom sought after. Thus, all early explorers attempted to carry a complete supply of food with them.

Hudson was the first of the explorers to winter in the American Arctic, a wintering that was not anticipated.[216] When he found himself ice-locked in early winter he had only two months provisions left. Under such straits, Hudson organized hunting parties which were only partially successful. They managed to survive the winter, some of the crew returning to Europe.[217]

After Hudson, there were many winterings in the Arctic, some intentional, some not. Many of both types were able to supplement their food supply from local sources, though to only a limited extent. Button, who wintered at Port Nelson, ". . . was supplied with great store of white Partridges (Ptarmigan) and other fowls, . . . this company killed 1800 dozen in the Winter season."[218] Nevertheless, Button lost many men, as did most other wintering parties.

Most of the game obtained by the wintering parties was shot. Munk writes, for example, that his

[216] Frobisher was the first explorer to plan for an extended stay in the Arctic. Although his plans aborted, he carried sufficient provisions to last eighteen months.

[217] This crew also became the first group of Europeans to utilize stored food in the American Arctic. They stopped at a bird cache that the Eskimos had made in order to replenish their larder.

[218] Christy, *op. cit.*, p. 167.

> . . . crew went on shore to pursue game in the day time. Part went to the forest to set traps and some built a hut wherein to lie for glug, . . . others took to open country to shoot because [there were] plenty of ptarmigan . . .[219]

Despite all of these hunting efforts, Munk's group had a disastrous winter and all but three died. These three regained their health by eating grass and by catching flounders with a net after June 18 when the ". . . ice drifted away from the ship, . . ."[220]

Although most of the early winterings were unintentional, during the nineteenth century winterings were planned as a necessary part of arctic exploration. Such plans included the stocking of fu l and food to last for several years. As long as the explorers stayed with their ships such a food supply would suffice, for generally there was room enough on board to carry all that was needed.

When, however, exploration by sledge was developed, weight and space became very important. Nevertheless, the early sledgers continued to carry all of their food and fuel. One of Stefansson's most severe criticisms of the early explorers in the Arctic is that they had complete dependence upon a food supply that they could carry with them which, if, and when, it was consumed meant starvation.

Dependence, even partial, upon food from the area came slowly. The first such dependence involved the use of Eskimo hunters, who, as members of the party, supplied food through their prowess in hunting. Hearne, of the Hudson's Bay Company, and McClintock, a British explorer, were among the first to increase the length of their journeys by such a method and Peary used it in his North Pole marches.

The actual utilization of Eskimo methods by explorers themselves was infrequent, primarily, it seems, because most explorers believed that Eskimo techniques could not be utilized successfully by civilized man. Stefansson advanced this method of exploration more than any other individual. By combining the rifle with Eskimo techniques Stefansson was able to explore vast areas of land and sea (over the ice) while depending entirely upon the environment for his food supply.

Settlers in the Arctic

Most permanent settlers in the Arctic today only incidentally add to their food supplies from natural sources. There are several reasons for such lack of use of natural food sources. Most non-natives in the Arctic are engaged in full-time occupations that do not allow hunting and fishing except as sport. Also, large land game animals in most of the Arctic are protected by law.

Thus, there is relatively little attempt on the part of most settlers to supplement their food supply. There have also been only a few attempts to add to it by agriculture and herding. Agriculture under present technology is not feasible in most of the Arctic. Only in the valleys of southern Greenland has some cultivation, mostly hay but also some vegetables, been successful without the use of hothouses.

Attempts at utilizing the tundra vegetation for grazing have been made. Although reindeer herding is old in the Arctic of the Eastern Hemisphere, it was only recently introduced into the Americas where, for a variety of reasons, it failed. In southern Greenland since the mid-twenties, sheep have been successfully herded on an expanding scale. Milk cows and horses are used in the local economy. As these animals, unlike the caribou and musk ox, are not native to this type of environment, much care must be exercised in their husbandry. Protective measures against snow as well as cold have to be utilized through much of the year and supplemental feeding is necessary.

Survival

All handbooks on the Arctic discuss the type of available food and describe, usually in a more or less modified form, the Eskimo techniques of acquiring it. A working knowledge of such practices is invaluable for persons likely to be caught away from a base of operations. The disastrous results of the lack of such information is well indicated in the summary of World War II experiences made by Howard, as discussed above.[221]

[219] Gosch, *op. cit.*, p. 31.
[220] *Ibid.*, p. 59.
[221] *Supra*, p. 166.

Snow, Ice, and Permafrost and Food Storage

During much of the year natural cold storage is present throughout the Arctic because of the extremely low temperatures which prevail. Foods which are not injured by low temperatures can be stored almost anywhere during winter. The major precaution that must be taken is to protect the stored items from predators. It is the summer season that provides the most difficult problems in food storage.

Eskimos

As most of the Eskimos were nomadic, especially during the summer, storage of food was not a highly developed art. During winter they took advantage of the low temperatures to preserve their food. In former times racks were frequently built upon which boats, skins, and food were stored. Today, the roofs of buildings frequently serve the same purpose. During the summer the most sedentary of the Eskimos dig storage pits or cellars in the permafrost. Spencer, in describing the ice cellars of the Alaskan Eskimos, writes that.

> Although quite large and spacious today, the aboriginal cellars were smaller, cut laboriously into the permafrost with bone picks. The cellar was supported with whale ribs and a whale skull placed at the entrance, the roof covered with sod. Virtually every household had its own cellar where meat of all kinds was stored.[222]

These storage pits and cellars usually contained predominantly one type of meat but in actuality they were catch-alls. For example, along the Yukon the pits were made primarily for salmon but, if any other food was to be stored, it would be placed in the pits too.[223] Such permafrost pits were usually not cold enough to prevent all decay.

Although Eskimo summer storage depended on permafrost conditions, in winter storage the Eskimos frequently made use of ice and snow also. Generally, however, snow and ice are used only as a temporary expedient, although they are used in a variety of ways. One method is to bury the food to be preserved or protected in the snow. Murdoch writes that a Point Barrow Eskimo who has been successful in a winter hunt

> . . . usually "butchers" him [caribou] on the spot, and brings in as much of the meat as he can carry on his back, leaving the rest, carefully covered with slabs of snow to protect it from foxes, to be brought in as soon as convenient by a dog sled, which follows the hunter's tracks to the place.[224]

Among the Central Eskimos, seal and reindeer are so buried, as are fish.[225]

Those hunters who have dogsleds with them are usually able to transport the catch home without depending on temporary storage. Snow is also used in preparing animals for transport. Herendeen has written that after the pelt has been removed from a caribou, its carcass is placed

> . . . in a pit which the hunter excavates in the snow just the length of the body of the deer, with the neck turned at a right angle, and the nose pointing upward, to lengthen one leg of the angle. In this shape the carcass freezes. . . .[226]

Carcasses thus frozen can be stacked efficiently on a sled for transport. In between the heads are placed the pelts which have been dried on the snow after cleaning.[227]

Storage under or in the snow may be somewhat more permanent. Crantz, for example, writes that the Eskimos of Greenland who use regular storehouses during the summer preserve ". . . all that they catch in winter under the snow, . . ."[228]

Those Eskimos who live in snowhouses usually construct a special storage room off the entrance tunnel (Figure 54). Occasionally, however, a separate small snowhouse for storage only will be built. Outside the snowhouse region special anterooms may be used or food may be stored in the entrance tunnel itself. Such places are natural refrigerators from which the meat is brought into the living part of the igloo to thaw some time prior to use.

Ice is used in a variety of ways for storage. The Point Barrow Eskimos, on their fall inland

[222] *The north Alaskan Eskimo* (Washington: Smithsonian Institution, Bureau of American Ethnology, Bulletin 171, 1959), p. 60.
[223] Pike, "Through the subarctic forest. . . ." (London: E. Arnold, 1896), p. 259.
[224] *Op. cit.*, p. 264.
[225] Ross, *op. cit.*, p. 166.
[226] As quoted in Sonnenfeld, *op. cit.*, p. 144.
[227] *Idem.*
[228] *Op. cit.*, p. 141.

 *Figure 54. Storage room along entrance tunnel of igloo. Note the clear-ice window.*	 *Figure 55. Meat storage on top of snow blocks.*

hunts, build ice houses from newly formed river ice, in which they store both caribou and fish.[229] Another frequent use of ice is in the construction of a cache. After the meat is piled up and turf piled on top, water is poured over the pile. The water freezes, giving a protective cover of ice. This cover not only makes the cache difficult to enter but also destroys the scent of man which would attract predators.[230] Frequently the Eskimos will form a cache by placing meat in shallow ponds so that when these ponds freeze the meat is protected.[231]

During winter the only real problem in storage is protection from predators. Stands of various types suffice by placing the stored items out of a predator's reach. The materials used may be snow blocks, as illustrated in Figure 55.

From the standpoint of storage, snow is more of a disadvantage than an advantage. It is the low temperature that preserves, so preservation could be accomplished without snow. However, drifting snow may cover the stored items to such an extent that their location may be lost unless some method is used to mark the spot. One of the most frequent methods used by the Eskimo is to use part of the animal such as the horns of a caribou. Some hunters have specially prepared indicators. Among the Point Barrow Eskimos, " . . . little ivory rods, each with a little bunch of feathers tied to one end, [illegible] are used. This same group often uses the animal itself as an indicator. When visibility is poor on the sea ice the hunter stands his solidly frozen seals in the snow so that the villagers who come out to collect them have no difficulty locating the catch.[233]

Explorers and Food Storage

The storage of food by explorers presented no major problems. In summer these men were on the move and they carried their food with them, whether on board ship or on their sleds. In winter, instead of using specially constructed storage houses, most explorers left their food stored on board the ships in which they wintered. For insurance against fire most winterers built a storehouse on shore in which they could place some emergency supplies.

Those explorers who went over land frequently made special storehouses out of snow, as did Rae, when he wintered at Repulse Bay.[234] Yet other explorers cut holes in ice and, after they had stored the food inside the hole, the opening was " . . . frozen over by pouring water upon it and covering by snow . . ." a technique borrowed from the Eskimos or Indians.[235]

Present Day Storage

Shallow-pit storage was used by the Eskimos and possibly to some extent by a few explorers. Despite a rather early knowledge of the advantage of permafrost preservation, its large-scale use is of recent origin, a fact which is apparently as true in the Soviet Union as in the American Arctic. Rae, at Barrow in 1882, converted a pit he

[illegible]

[illegible] p. 84.

R[illegible] London: The Hudson's Bay Record Society, [illegible] p. 88.

[illegible] p. 240. Possibly one of the most effective [illegible] techniques used by explorers is that described [illegible] Expedition [illegible] Proceedings of the United [illegible] XXX [illegible] a hole [illegible] deep [illegible] where the fire had thawed it [illegible] spruce boughs [illegible] the ashes [illegible] The heat melting [illegible] the ashes [illegible] freeze solid. The ice [illegible] p. 869.

had dug for temperature measurements into a subterranean storehouse which proved very successful and which was taken over for private use by Brower in 1884. According to Stefansson, it was this deep permafrost storage that first acquainted the Eskimos with the possibilities of permanent preservation rather than their traditional temporary storage in surface pits. This type of storage spread rapidly throughout western and northern Alaska.[236]

This idea also spread via whalers into northwestern Canada and permafrost cellars became important in the Mackenzie Delta area. At Aklavik such storage was more intensively used than elsewhere in the Canadian Arctic for the people stored ice as well as food in their cellars. This stored ice furnished much of their summer water supply.[237]

In much of Canada, the possibility of such vertical permafrost storage cellars is more limited than in most of Arctic Alaska, because much of the land area of Canada is of Canadian Shield origin and has bedrock near the surface. Although vertical pits, because of the cold air trap they provide, are the best type of permafrost cellars, in many areas horizontal structures must be used.

Large-scale preservation became a necessity at the time of the temporary boom in the reindeer industry early in the present century. The world's first large natural cold-storage plant was constructed at Elephant Point, Alaska. It consisted of a large storage room constructed at the end of a long tunnel which was dug into the side of a frozen hill. Such an extensive structure has apparently not been duplicated since.

At isolated settlements and some federal installations the storage problem is solved by the construction of small permafrost cellars. The United States Weather Bureau has developed a standardized wooden permafrost reefer which it has had constructed at several of its weather stations in the Arctic. These reefers, measuring eight by eight by six feet in size, are buried about four feet beneath the surface of the ground. The trend today at government installations, including some of the weather stations, is to use mechanical refrigerators.

[236] Stefansson, "Natural cold storage," *The Dynamic North*, II, no. 13, 9.

[237] *Ibid.*, p. 16.

In storing supplies in the Arctic today the problem of a temperature that is too low often has to be considered. Many foods are damaged by low temperatures and thus cannot be stored outside during winter.

Other methods of food storage are used in the Arctic. As early as the mid-eighteenth century an ice house was present at Hay River. It was filled every spring with ice from the river and food was stored safely throughout the summer. At some coastal locations ice houses are frequently filled with sea ice and even pieces of icebergs. Storage in caves carved in glaciers has been tried. At one of the DEW Line sites on Baffin Island the construction foreman used this technique. His storage cave was successful for about one year but the glacier's movement finally forced its abandonment. Current field investigations in ice caves and tunnels in Greenland will certainly increase the knowledge of their use for food storage.

Although some experimentation has been carried on in the construction of permafrost storage pits for bulk storage, little experimenting has been directed toward the construction of ice cellars in the American Arctic. The Russians, however, have developed a workable type of structure that is capable of storing some 100 metric tons of foodstuffs. A large wooden framework with matting on it is sprayed with water until an ice-coating two meters thick is formed.

> Niches are now cut in the inside of the walls about 1.5 m. high and 0.6 m. deep. In each of these is placed a barrel containing lumps of ice, with a slatted crate on top of it containing ice mixed with 3 to 5 kg. of salt. The effect of this is to lower the temperature of the air below 0° C. . . . The whole structure is now covered with sawdust, ash, turf, moss or earth. . . .[238]

Such structures have lasted over fourteen years in the Moscow area. Apparently nothing comparable has been attempted in the American Arctic.

[238] Krylov, "Soviet ice cellars," *The Polar Record*, VIII, no. 57 (1957), p. 558.

Summary and Conclusions

An attempt has been made to present briefly the nature, distribution, and availability of the several water and food sources present in the American Arctic and to detail the techniques and equipment man has developed in his attempts to ensure an adequate supply of these two primary needs under nature-imposed conditions of snow, ice, and permafrost. Members of the three basic, yet contrasting, groups (the Eskimos the explorers, and today's non-Eskimo residents), all of whom have been intimately associated with the Arctic, have had to concern themselves with snow, ice, and permafrost as they are related to water and food supply. The requirements, sources, and techniques have all varied, and indeed vary today, from the members of one group to those of another and also they have varied with time within each group. In the case of water, today's inhabitant demands not only improved quality but a much greater quantity than did either the Eskimos or explorers; whereas, in the case of food, the main requirement contrast between the Eskimos and non-Eskimos is one of quality, for quantity consumed has remained about the same.

Snow, ice, and permafrost have a close but varied relationship to arctic water supply. In summer much water becomes available through the melting of surface snow and ice and the thawing of the active layer, although it is frequently poor in quality according to today's health codes. Even in summer snow and ice are frequently used on the Greenland Ice Cap and on the drifting ice stations in the arctic pack.

In winter snow, ice, and permafrost prevent the easy acquisition of water in the liquid state (the most desirable form), but, at the same time, they become sources themselves. The most important of the winter sources for most of the Eskimos at the present time, as well as in the past, is ice. However, sub-ice lake water is significant to some groups. The same sources were used by the explorers and the early inhabitants in the Arctic. They are still used by many of the non-Eskimo residents although the most important source is becoming sub-ice lake water, if it has not already attained that status. To date, few attempts have been made to establish wells in the permafrost in the Arctic and those which have been tried have been unsuccessful except in a few localities where summer-use-only wells exist.

Thus, the sources used for water today are the same as those used by the Eskimos and the explorers. Techniques, however, are different. Man, though unable to increase the available sources (to the present time, at least), has increased the ways these sources can be exploited and the amount of water that can be produced and stored. Because of the difficulty of converting snow and ice and of maintaining water in a liquid state, the Eskimos and explorers reduced their demands to a minimum. Today's residents, with demands of greater quantities, have developed, although not perfected, mass production and large storage techniques.

The preference among all three groups has been the liquid form when obtainable. During the cold season, which extends over most of the year, this form of water can be obtained only from under the capping layer of ice which forms on all lakes and rivers in those areas where these bodies of water are sufficiently deep not to freeze to the bottom. Although no accurate survey exists to the present of the location of such lakes, there are certain areas in which this type of source is not present because of shallowness. The most extensive of such areas in the American Arctic is found in the glaciated Canadian Shield. The techniques developed by the "stone-age" Eskimos were adequate for digging through this ice but only with great labor, and the method was used only in the region where an inadequate source of fuel necessitated the use of a source other than snow or ice. In those areas where lakes freeze to the bottom (therefore, no liquid water is present) or where an adequate supply of fuel is available, ice and snow were melted. Explorers for the most part, unless accompanied by natives (a rare occurrence), used ice and snow as their only source of winter water. Today a larger percentage of water consumed in the Arctic is coming from beneath the ice in lakes or rivers than in previous times. Most locations along the coast of northern Canada and Alaska can provide such water with relatively short hauls. Primarily responsible for today's emphasis on sub-ice lake water is the capability of maintaining an open water hole usually by a heated hut, of hauling water in a heated wanigan, and a bulk storage in heated containers. Indeed, with such techniques winter water supply may be easier to obtain than summer supply because of improved transport conditions which make longer hauls possible. Nevertheless, there are still many regions in today's Arctic where ice and or snow must be melted for water in winter. Mass production techniques are now used in mining, hauling, and melting the ice and in delivering the water.

Although the same sources of water are being used in the Arctic today as in the past, there is a greater emphasis on the liquid source. One of the conditions limiting this type of supply is the extremely low temperature that prevails in the Arctic, a condition that necessitates heated storage. Because of the added convenience and efficiency of water in the liquid state, a great deal of effort is being expended today in establishing heated tank storage. Such tanks, even in shallow lake areas, can be filled in summer. To date they are limited to a few government installations; however, if, and when, they become practical for general settlement in the Arctic (and this condition will probably exist before the development of a ground source becomes practical), man's dependence upon snow and ice as a source of water will be nearly eliminated except for field operations. Until then, however, ice and snow will continue to be the only winter source of water over many parts of the Arctic and, despite some improved techniques, their conversion into water appears destined to remain for some time to come an expensive and time-consuming operation.

In the case of food supply in the Arctic, a somewhat different situation has evolved. The Eskimos depended entirely on their environment for all of their food; few still do. They developed techniques of acquiring this food—nearly all of which was animal food—that were adapted to an environment characterized by snow and ice. Their hunting techniques, especially those connected with the sea mammals in general and the seals in particular, utilized ice characteristics as well as animal habits to a high degree. The explorers who entered the environment with the notion that it was virtually lifeless, imported all of their food, a trend that with few exceptions has continued to the present day. The explorers did it because they did not at first realize there was adequate life for supplying them food. Once they realized that such life existed, however, they did not have adequate techniques to take advantage of it and were reluctant to adopt the satisfactory techniques of the Eskimos. Today's non-Eskimo populace expends most of its energy and time in the pursuit of occupations other than hunting and thus must depend upon food from other regions. Another factor necessitating such dependence is the demand of a varied diet—a diet composed of items that cannot be obtained in the Arctic. There is the possibility, as is being demonstrated to some extent by the Russians, that the future of the Arctic holds some food production capabilities—possibly a revitalization of reindeer herding and the development of a limited agriculture. However, present indications are that such developments will not be forthcoming in the near future. Much has yet to be learned about the nature of the Arctic, including detailed information about snow, ice, and permafrost, before agriculture can become very significant. Food will continue to be imported, albeit, at a high cost. Part of such cost is for storage, for generally large amounts of food must be brought in at one time—in many places by ship once a year, in most at more frequent intervals by air. Storage techniques, including specially constructed permafrost reefers, are gradually being improvised. However, such developments in the American Arctic have lagged far behind similar developments in the Soviet Union.

Through increased mechanization, the relationship of snow, ice, and permafrost to water and food spuply (especially the latter) is becoming more tenuous with time and with the increased numbers of non-Eskimos in the Arctic. Instead of the complete dependence upon the environment of the pre-contact Eskimo, man today only partially relies on the Arctic itself to supply his needs. In the process of attaining this state the non-native has failed to utilize the effective (through relatively low-yielding) techniques developed by the Eskimos and, indeed, the Eskimos today are gradually losing many of these techniques themselves.

Complete dependence upon products from areas outside the Arctic may lead to disaster today just as it did so frequently in the days of the early explorers. Although man in the Arctic generally has a choice of sources of food and water which can be utilized under survival conditions, he can capitalize on them only by possessing adequate techniques. To date, a knowledge of the techniques developed by the Eskimos, many of which depend upon or are related to snow and ice, is the best insurance against disaster when the problem of survival arises in the Arctic.

Bibliography

The parenthetical numbers following the bibliographical entries refer to the catalogue numbers as listed in the *Arctic Bibliography* 1953–1959, eight volumes, prepared for and in cooperation with The Department of Defense under the direction of The Arctic Institute of North America. The *Arctic Bibliography* has been used as a guide in the arrangement of the works listed below.

Books

The arctic world: its plants, animals and natural phenomena. London: T. Nelson & Sons, 1876. Pp. vii + 276.

Armstrong, Alexander. *A personal narrative of the discovery of the Northwest Passage.* London: Hurst & Blackett, 1857. Pp. xxii + 616. (AB 682).

Back, George. *Narrative of the Arctic Land Expedition.* Philadelphia: E. L. Carey & A. Hart, 1836. Pp. ix + 456. (AB 853).

Bertram, Colin. *Arctic and Antarctic: the technique of polar travel.* Cambridge, England: W. Heffer & Sons, Ltd., 1939. Pp. xii + 125. (AB 1940).

Bilby, Julian W. *Among unknown Eskimo; an account of twelve years intimate relations with the primitive Eskimo of ice-bound Baffin Land, with a description of their ways of living, hunting customs & beliefs.* London: S. Service & Co., Ltd., 1923. Pp. 280. (AB 1550A).

Birket-Smith, Kaj. "The Caribou Eskimos, material and social life and their cultural position. I. Descriptive part." *Report of the Fifth Thule Expedition, 1921–24.* Vol. V. Copenhagen: Gyldendal, 1929. Pp. 310. (AB 1606).

———. "The Caribou Eskimos, material and social life and their cultural position. II. Analytical part." *Report of the Fifth Thule Expedition, 1921–24.* Vol. V. Copenhagen: Gyldendal, 1929. Pp. 419. (AB 1606.)

———. *The Eskimos.* New York: E. P. Dutton & Co., 1936. Pp. 250. (AB 1611).

———. "Ethnographical collections from the Northwest Passage." *Report of the Fifth Thule Expedition, 1921–24.* Vol. VI, No. 2. Copenhagen: Gyldendal, 1945. Pp. 298. (AB 1612).

———. "Geographical notes on the Barren Grounds." *Report of the Fifth Thule Expedition, 1921–24.* Vol. I, No. 4. Pp. 128. Copenhagen: Gyldendal, 1933. (AB 1621).

———. "The Greenlanders of the present day," in *Greenland.* Vol. II. London, 1928. Pp. 1–207. (AB 1623).

Blake, Euphemia Vale (ed.). *Arctic experiences, containing Capt. George E. Tyson's wonderful drift on the ice-floe, a history of the Polaris Expedition, the cruise of the Tigress and rescue of the Polaris survivors.* New York: Harper & Bros., 1874. Pp. 486. (AB 1694).

Boas, Franz. "The Central Eskimo." *Sixth annual report of the Bureau of American Ethnology, 1884–85.* Washington: U.S. Government Printing Office, 1888. Pp. 399–669. (AB 1728).

Burton, Alan C., and Edholm, O. G. *Man in a cold environment: physiological and pathological effects of exposure to low temperatures.* London: Edward Arnold, 1955. Pp. xiv + 273. (AB 39081).

Christy, Miller (ed.). *The voyage of Captain Luke Foxe of Hull, and Captain Thomas James of Bristol, in search of a north-west passage, in 1631–32.* London: Printed for the Hakluyt Society, 1894. 2 Vols.: No. 88, pp. ccxxxi ± 258; No. 89, pp. 681.

Collinson, Richard (ed.). *The three voyages of Martin Frobisher in search of a passage to Cathaia and India by the north west, A.D. 1576–8.* London: Printed for the Hakluyt Society. 1867. No. 38, pp. xxvi + 376.

Courtauld, Augustine. *[illegible] n the ends of the Earth.* London: Oxford University Press, 1958. Pp. xvi + 419.

Crantz, David. *The history of Greenland;* . . . London: Longman, Hurst, Rees, Orme, & Brown. 1820. 2 Vols.: pp. xi + 359; pp. vi + 383. (AB 3472).

de Coccola, Raymond, and King, P. *Ayprama.* Toronto: Oxford University Press, 1955, Pp. ix + 316. (AB 39305).

de Poncins, Gontran. *Kabloona.* New York: Reynal & Hitchcock, Inc., 1941. Pp. xii + 339. (AB 13701).

de Veer, Gerrit. *The three voyages of William Barents to the arctic regions (1594, 1595, and 1596).* London: Printed for the Hakluyt Society, 1876. No. 54, pp. clxxiv + 289.

Dooner, Kai. *Among the Samoyed in Siberia.* Trans. Rinehart Kylor. New Haven: Human Relations Area Files, 1954. Pp. xx + 176. (AB 39576).

Driver, Harold E., and Massey, William C. "Comparative Studies of North American Indians." *Transactions of the American Philosophical Society.* New Series, Vol. XLVII, pt. 2, 1957. Pp. 165–456.

Driver, Harold E., *et al.* "Indian tribes of North America." *Indiana University Publications in Anthropology and Linguistics.* Indiana University Press, 1953. Memoir 9, pp. 30.

Dunbar, Moira, and Greenaway, Keith R. *Arctic Canada from the air.* Ottawa: Queen's Printers, 1956. Pp. 541.

Eisberg, H. B., and Owens, J. E. *Fundamentals of arctic and cold weather medicine and dentistry.* Washington: U.S. Navy, Bureau of Medicine and Surgery, 1949. Pp. xii + 204. (AB 4423).

Glider, William Henry. *Schwatka's search; sledging in the Arctic in quest of the Franklin records.* New York: C. Scribner's Sons, 1881. Pp. xvi + 316. (AB 5745).

Gosch, C. A. A. (ed.). *Danish arctic expeditions, 1605–1620.* London: Printed for the Hakluyt Society, 1897. 2 Vols.: No. 96, pp. cxvii + 205; No. 97, pp. cxviii + 187.

Greely, Adolphus Washington. *Three years of arctic service: an account of the Lady Franklin Bay Expedition of 1881–84, and the attainment of the farthest north.* New York: C. Scribner's Sons, 1886. 2 Vols.: Pp. xxv + 428; pp. xii + 444. (AB 6118).

Hall, Charles Francis. *Arctic researches and life among the Esquimaux.* New York: Harper & Bros., 1865. Pp. x + 595. (AB 6485).

Hanbury, David T. *Sport and travel in the northland of Canada.* New York: Macmillan Co., 1904. Pp. xxxii + 319. (AB 6550).

Helmericks, Bud. *Arctic hunter.* Boston: Little, Brown & Co., 1955. Pp. 142.

Hobbs, William Herbert. *Peary.* New York: Macmillan Co., 1936. Pp. xv + 502. (AB 7160).

Holmes, Lewis. *The arctic whaleman.* Boston: Wentworth, 1857. Pp. 296. (AB 7321).

Hooper, C L. *Cruise of the Corwin.* Washington: U.S. Government Printing Office, 1883. Pp. 120. (AB 18399).

Hostrup, Lyons & Associates. *Study of the mechanical engineering features of polar water supply.* Los Angeles: prepared for U. S. Naval Engineering Research and Evaluation Laboratory, Port Hueneme, California, 1953. Pp. 203. (AB 35341).

Hutton, Samuel King. *Among the Eskimos of Labrador; a record of five years' close intercourse with the Eskimo tribes of Labrador.* London: Seeley, Service & Co., Ltd., 1912. Pp. xviii + 343. (AB 7605).

Ingstad, Helge. *Nunamiut; among Alaska's inland Eskimos.* London: Ruskin House, 1954. Pp. 254. (AB 35378).

Jenness, Diamond. *Dawn in arctic Alaska.* Minneapolis: University of Minnesota Press, 1957. Pp. 222.

———. ———. *The people of the twilight.* New York: Macmillan Co., 1928. Pp. xii + 247. (AB 8048).

Johnson, Robert E., and Kark, R. M. *Feeding problems in man as related to environment. An analysis of United States and Canadian Army ration trials and surveys, 1941–1946.* Chicago: U.S. Army Medical Nutrition Laboratory, 1946. Pp. 94. (AB 8214).

Jones, T. Rupert (ed.). *Manual of the natural history, geology, and physics of Greenland and the neighboring regions.* London, 1875. Pp. 782.

Kane, Elisha Kent. *Arctic explorations: the Second Grinnel Expedition in search of Sir John Franklin, 1853, '54, '55.* Philadelphia: Childs & Peterson, 1856. 2 Vols.: Pp. 464; pp. 457. (AB 8373).

———. *The U.S. Grinnell Expedition in search of Sir John Franklin. A personal narrative.* New York: Harper & Brothers, 1854. Pp. xi + 552. (AB 8381).

Kimble, G. H. T., and Good, Dorothy (eds.). *Geography of the northlands.* New York: American Geographical Society and John Wiley & Sons, Inc., 1955. Pp. x + 543. (AB 40738).

Koldewey, Karl. *The German arctic expedition of 1869–70, and narrative of the wreck of the "Hansa" in the ice.* Translated and abridged by L. Mercier; edited by H. W. Bates. London: S. Low, Marston, Low, & Searle, 1874. Pp. viii + 590. (AB 9024).

Kroeber, Alfred L. *Cultural and natural areas of native North America.* Berkeley: University of California Press, 1947. Pp. xxxix + 242. (AB 40861).

Kumlien, Ludwig. *Contributions to the natural history of arctic America, made in connection with the Howgate Polar Expedition, 1877–78.* Washington: U.S. Government Printing Office, 1879. Pp. 179. (AB 9439).

Leslie, John. *Narrative of discovery and adventure in the polar seas and regions:* . . . New York: Harper & Bros., 1831. Pp. 373. (AB 9945).

Lyon, George Francis. *The private journal of Capt. G. F. Lyon, of H.M.S. Hecla, during the recent voyage of discovery under Capt. Parry.* London: J. Murray, 1824. Pp. xiii + 468. (AB 10531).

M'Dougall, George Frederick. *The eventful voyage of H.M. Discovery ship "Resolute" to the arctic regions* . . . London: Longman, Brown, Green, Longmans & Roberts, 1857. Pp. xl + 530. (AB 10603).

Markham, Albert Hastings (ed.). *The voyages and works of John Davis.* London: Printed for the Hakluyt Society, 1880. No. 59, pp. xcv + 392.

Markham, Clements R. (ed.). *The voyages of William Baffin, 1612–1622.* London: Printed for the Hakluyt Society, 1881. No. 63, pp. lix + 192.

Marshall, Robert. *Arctic village.* New York: Literary Guild, 1933. Pp. xii + 399. (AB 10974).

Mathiassen, Therkel. "Material culture of the Iglulik Eskimos." *Report of the Fifth Thule Expedition, 1920–24.* Vol. VI, No. 1. Copenhagen: Gyldendal, 1928. Pp. 242. (AB 11081).

Mawson, Douglas. *The home of the blizzard.* Philadelphia: J. B. Lippincott Co., 1914. 2 Vols.: Pp. xx + 349; pp. xii + 338.

Mirsky, Jeannette. *To the Arctic! The story of northern exploration from earliest times to the present.* New York: A. A. Knopf, 1948. Pp. xxi + 334. (AB 11527).

Muller, Siemon W. *Permafrost or permanently frozen ground and related engineering problems.* Ann Arbor: J. W. Edwards, Inc., 1957. Pp. ix + 231. (AB 11846).

Murdoch, John. "Ethnological results of the Point Barrow expedition." *Ninth annual report of the Bureau of American Ethnology, 1887–88.* Washington: U. Government Printing Office, 1892. Pp. 3–441. (AB 11883).

Nansen, Fridtjof. *Farthest north.* London: George Newnes, Ltd., 1898. 2 Vols.: Pp. xv + 480; pp. viii + 456. (AB 11984).

———. *The first crossing of Greenland.* London: Longmans, Green & Co., 1890. 2 Vols.: Pp. 510; pp. 509. (AB 11985).

———. *In northern mists: arctic exploration in early times.* London: W. Heinemann, 1911. 2 Vols.: Pp. 383; pp. 415. (AB 11993).

Nelson, Edward. "The Eskimo about Behring Strait." *Eighteenth annual report of the Bureau of American Ethnology, 1896–97.* Pt. 1. Washington: U.S. Government Printing Office, 1899. Pp. 3–518. (AB 12177).

Nordenskjold, Otto and Mecking, Ludwig. *The geography of the polar regions.* New York: American Geographical Society, 1928. Pp. vi + 359. (AB 24688).

Ostermann, Hother. "The Alaskan Eskimos as described in the posthumous notes of Dr. Knud Rasmussen." *Report of the Fifth Thule Expedition, 1921–24.* Vol. X, No. 3. Copenhagen: Gyldendal, 1952. Pp. 292. (AB 31547).

———. "Knud Rasmussen's posthumous notes on the life and doings of the East Greenlanders in olden times." *Meddelelser om Grønland,* Bd. CIX, nr. 1, 1938.

Parry, William Edward. *Journal of a third voyage for the discovery of a north-west passage.* London: J. Murray, 1826. Pp. xxvii + 186. (AB 13144).

Payer, Julius. *New lands within the Arctic Circle. Narrative of the discoveries of the Austrian ship "Tegetthoff," in the years 1872–1874.* London: Macmillan & Co., 1876. 2 Vols.: Pp. xxxi + 335; pp. xiv + 303. (AB 13202).

Peary, Robert Edwin. *Secrets of polar travel.* New York, Century Co., 1917. Pp. ix + 313. (AB 13238).

Pike, Warburton Mayer. *The barren ground of northern Canada.* London: Macmillan & Co., 1892. Pp. ix + 300. (AB 13527).

———. *Through the subarctic forest, a record of a canoe journey from Fort Wrangel to the Pelly Lakes, and down the Yukon River to the Behring Sea.* London: E. Arnold, 1896. Pp. xiv + 295. (AB 13528).

Rasmussen, Knud Johan Victor. "Intellectual culture of the Copper Eskimos." *Report of the Fifth Thule Expedition, 1921–24.* Vol. IX. Copenhagen: Gyldendal, 1932. Pp. 350. (AB 14210).

———. "Intellectual culture of the Iglulik Eskimos." *Report of the Fifth Thule Expedition, 1921–24.* Vol. VII, Pt. 1. Copenhagen: Gyldendal, 1929. Pp. 304. (AB 14211).

———. "The Netsilik Eskimos, social life and spiritual culture." *Report of the Fifth Thule Expedition, 1921–24.* Vol. VIII. Copenhagen: Gyldendal, 1931. Pp. 542. (AB 14223).

———. "Observations on the intellectual culture of the Caribou Eskimos." *Report of the Fifth Thule Expedition, 1921–24.* Vol. VII, Nos. 2 & 3. Copenhagen: Gyldendal, 1930. Pp. 114; pp. 160. (AB 14211).

Reynolds, Ernest Edwin. *Nansen.* London: Penguin Books, 1949. Pp. 283. (AB 25511).

Rich, E. E. (ed.). *John Rae's correspondence with the Hudson's Bay Company on arctic exploration.* London: The Hudson's Bay Record Society, 1953. Pp. cvi + 401. (AB 36959).

Rodahl, Kare. *North; the nature and drama of the polar world.* New York: Harper & Bros., 1953. Pp. 237. (AB 31667).

Ross, John. *Narrative of a second voyage in search of a north-west passage.* Paris, 1835. Pp. 475. (AB 14866).

Rostlund, Erhard. *Freshwater fish and fishing in native North America.* Berkeley: University of California Press, 1952. Pp. x + 313. (AB 37143).

Russell, Frank. *Exporations in the far North; being the report of an expedition under the auspices of the University of Iowa during the years 1892, '93, and '94.* The University, 1898. Pp. vii + 290. (AB 15019).

Ryder, T. *Compilation and study of ice thickness in the Northern Hemisphere.* New York: American Geographical Society, 1954. Pp. 19 + lx + 59 x 26.

Schwatka, Frederick. *Nimrod in the North; or, hunting and fishing adventures in the arctic regions.* New York: Cassell & Co., 1885. Pp. 198. (AB 15603).

Simpson, C. J. W. *North ice.* London: Hodder & Stroughton, 1957. Pp. 384.

Spencer, R. F. *The North Alaskan Eskimos, a study in ecology and society.* Bureau of American Ethnology, Bull. 71. Washington: U.S. Government Printing Office, 1959. Pp. vi + 490.

Steensby, Hans P. "An anthropogeographical study of the origin of the Eskimo culture." *Meddelelser om Gronland,* Bd. LIII, Nr. 2, 1905. Pp. 39–228. (AB 16732).

Stefansson, Viljalmur. *The Stefansson-Anderson Arctic Expedition.* New York: American Museum of Natural History, 1919. Pp. vii + 475. (AB 16862).

———. *Arctic manual.* New York: Macmillan & Co., 1944. Pp. xvi + 556. (AB 16785).

———. *The friendly Arctic, the story of five years in polar regions.* New York: Macmillan Co., 1921. Pp. xxxi + 784. (AB 16808).

———. *Hunters of the great North.* New York: Harcourt, Brace & Co., 1922. Pp. vii + 301. (AB 16817).

———. *My life with the Eskimo.* New York: McMillan Co., 1951. Pp. ix + 538. (AB 16832).

Steinert, Walther. *Die wirkung des Landschaftszwanges auf die materielle Kultur der Eskimo.* Hamburg: Ph.D. dissertation, 1935. Trans. A. Herling, ADTIC, Maxwell Air Force Base, Alabama. Pp. 62. (AB 26419).

Sverdrup, Otto N. *New land; four years in the arctic regions.* London: Longmans, Green, 1904. 2 Vols.: Pp. xvi + 496; pp. xii + 504. (AB 17322).

Tanner, Vaino. "Outlines of the geography, life and customs of Newfoundland-Labrador." *Acta Geographic.* Helsinki: Helsingfors, 1944. Pp. 906. (AB 17407).

Thalbitzer, William C. "Ethnographical collections from East Greenland (Angmagsalik and Nualik) made by G. Holm, G. Amdrup and J. Petersen." In Thalbitzer, W. C. "The Ammassalik Eskimo." *Meddelelser om Grønland,* Bd. XXXIX, 1914. Pp. 319–755. (AB 17553).

Thurston, W. R. (ed.). *Arctic sea ice.* Washington: National Academy of Sciences-National Research Council, Pub. 598. Pp. 271.

Tomlinson, Charles. *Winter in the arctic regions and summer in the Antarctic regions.* London: Clarendon Press, 1872. Pp. viii + 368. (AB 17881).

Turner, Lucien McShaw. "Ethnology of the Ungava District, Hudson Bay Territory." *Eleventh annual report of the Bureau of American Ethnology, 1889–90.* Washington: U.S. Government Printing Office, 1894. Pp. 159–350. (AB 18093).

Weyer, Edward Moffat. *The Eskimos; their environment end folkways.* New Haven: Yale University Press, 1932. Pp. xvii + 491. (AB 19363).

Whitney, Caspar. *On snow-shoes to the Barren Grounds; twenty-eight hundred miles after musk-oxen and wood-bison.* New York: Harper & Bros., 1896. Pp. x + 324. (AB 19410).

Articles and Periodicals and Reports

Alter, Amos J. "Water supply problems in low temperature areas." *Alaskan Science Conference . . . 1950, Selected papers* (1952), 219–239. (AB 20162).

Anderson, Rudolph Martin. "Report on the natural history collections of the expedition," in Stefansson, *My life with the Eskimo* (1951), 436–527. (AB 16832).

"Arctic water supply: it must circulate or freeze," *Engineering News-Record,* CLII, No. 5 (1954), 30–31.

Armstrong, Terence. "The ice of the central polar basin," *The Journal of Glaciology,* III, No. 22 (1957), 103–110.

Bagnall, V. B. "Building the distant early warning line," *The Military Engineer,* XLVII, No. 320 (1955) 429–432. (AB 38645).

Baird, Patrick D. "Canadian arctic Archipelago," in Kimble and Good, *Geography of the northlands* (1955), chap. XVII, 353–371. (AB 40738).

Bilello, M. A. "A survey of arctic snow-cover properties as related to climatic conditions," *SIPRE Report 39* (1957), pp. iv + 9.

Black, R. F. "Permafrost: a review," *Bulletin of the Geological Society of America,* LXV, No. 9 (1954), 839–855. (AB 33613).

———. "Permafrost as a natural phenomenon," *The dynamic North,* II, No. 1 (1956), pp. iv + 12. (AB 44041).

———. "Precipitation at Barrow, Alaska greater than recorded," *Transactions, American Geophysical Union,* XXXV, No. 2 (1954), 203–207. (AB 33614.)

Boughner, C. C. and Potter, J. G. "Snow cover in Canada," *Weatherwise,* VI, No. 6 (1953), 155–159, 170–171. (AB 38952).

Boyd, William L. "Limnology of selected arctic lakes in relation to water supply problems," *Ecology,* XC (1959), 49–54.

Boyd, W. and Boyd J. "Water supply problems at Point Barrow," *Journal, American Water Works Association*, LI, No. 7 (1959), 890–896.

Brewer, M. C. "The thermal regime of an arctic lake," *Transactions, American Geophysical Union*, XXXIX, No. 2 (1958) 278–284.

Burwash, Lachland Taylor. "Across arctic Canada, 1925–1926," *The Geographical Journal*, LXXIV (1929), 553–568. (AB 2548).

Cederstrom, D., Johnston, P., and S. Subitzky. "Occurrence and development of ground water in permafrost regions," *Geological Survey Circular 275* (1953), pp. 30.

Corton, Edward L. "A study of the arctic ice pack," *Transactions, American Geophysical Union*, XXXV, No. 2 (1954), pp. 375. (AB 34242).

Comer, George. "Whaling in Hudson Bay, with notes on Southampton Island," *Anthropological Papers-Boas Anniversary Volume*, New York (1906), 475–484. (AB 3358).

Court, Arnold. "Wind chill," *Bulletin, American Meteorological Society*, XXIX, No. 10 (1948), 487–493. (AB 3440).

Courtauld, A. "Living alone under polar conditions," *Polar Record*, No. 4 (1932), 66–74. (AB 3442).

Crary, Albert P. "Arctic ice island, and ice shelf studies, part 1," *Arctic*, XI, No. 1 (1958), pp. 42.

Crary, Albert P. and Browne, I. "Probable ice island locations in the Arctic Basin," *AFCRC Technical Report 54-10* (1954), pp. 9. (AB 34261).

Cronkwright, A. B. "Water supply problems of the Arctic," *Public Works*, LXXVIII (1947), 18–20. (AB 28641).

Davis, John. "The seamans secrets," in Courtauld, *The ends of the Earth* (1958), 73–85.

Diamond, Marvin. "Air temperature and precipitation on the Greenland Ice Cap," *SIPRE Report 43* (1956), pp. iv + 9.

———. "Precipitation trends in Greenland during the past 30 years," *SIPRE Research Report 22* (1956), pp. iv + 4. (AB 44615).

Diamond, Marvin and Gerdel, R. W. "Occurrence of blowing snow on the Greenland Ice Cap," *SIPRE Report 25* (1957), pp. iv + 5.

Dmitrieva, N. G. "Calculation of snow-cover density using meteorological data," *SIPRE Translation 24* (1954), pp. 4.

Dunbar, Maxwell J. "Water masses, circulation, ice cover," in Kimble and Good, *Geography of the Northlands* (1955), chap. III, 36–57.

Dunbar, Moira and others. "Historical references to ice islands," *Arctic*, V, No. 2 (1952), 83–95. (AB 23348).

Ekblaw, Walter Elmer. "The ecological relations of the Polar Eskimo," *Ecology*, II (1921), 132–144. (AB 4433).

Espenshade, E. and Schytt, S. "Problems in mapping snow-cover," *SIPRE Report 27* (1956), pp. vi + 92.

Flint, Richard F. "Snow, ice and permafrost in military operations," *SIPRE Report 15* (1953), pp. 6.

Foster, L. R. R. "Watering ships in pack ice," *The Polar Record*, VII, No. 47 (1954), 52-53. (AB 34738).

Frank, Bernard. "The story of water as the story of man," in *Water*, Washington: Government Printing Office (1955), chap. 1, 1–8.

Hadley, R. "Whaling off the Alaskan coast," *Bulletin, American Geographical Society*, XLVII (1915), 905–921. (AB 6435).

Hare, Frederick K. "The climate of the American northlands," *The dynamic North*, I, No. 3 (1956), pp. 33. (AB 45436).

Hare, Frederick K. and Montgomery, M. R. "Ice, open water, and winter climate in the eastern Arctic of North America; Part I. - Part II," *Arctic*, II, No. 2 (1949) 79–89 and II, No. 3 (1949), 149–164. (AB 6655).

Harwood, T. A. "A further account of tragedy on the coast of Cumberland Gulf," *The Arctic Circular*, II (1959), 73–74.

Herendeen, E. P. "An Esquimaux caribou hunt," *Forest and Stream*, XXXVIII (1892), p. 249.

Holmes, G. W. "Morphology and hydrology of the Mint Julep area, southwest Greenland," *Project Mint Julep*, ADTIC Pub. A–104B (1955), pt. II, 1–50. (AB 42959).

Holmes, G. W. "Topographic and hydrologic studies," *Project Mint Julep*, ADTIC Pub. A–104A (1955), pt. I, 1–82. (AB 42958).

Howard, Richard A. "Down in the North; an analysis of survival experiences in arctic areas," *ADTIC Pub. A–103* (Maxwell Air Force Base, 1953), pp. vi + 50. (AB 29712).

Hutchins, Robert. "On airs, waters, and places," *Great Books of the Western World: 10 Hippocrates; Galen*, Encyclopedia Britannica, Inc., Chicago (1952), pp. 215.

Hyland, W. L. and Mellish, M. H. "Steam heated conduits—utilidors—protect service pipes from freezing," *Civil Engineering*, XIX, No. 1 (1949), 27–29, 73. (AB 7672).

Jeffers, Karl B. "Triangulation parties conquer arctic to map Alaska," *Civil Engineering*, XXI, No. 2 (1951), 34–37. (AB 22948).

Jenness, Diamond. "The Copper Eskimos," *Geographical Review*, IV (1917), 81–91. (AB 8028.)

———. "The Eskimos of northern Alaska; a study in the effect of civilization," *Geographical Review*, V (1918), 89–101. (AB 8033).

Jenness, John L. "The physical geography of the waters of the western Canadian Arctic," *Geographical Bulletin*, No. 4 (1953), 32–64. (AB 29864).

Johnson, R. E. and Kark, R. M. "Environmental caloric requirements," *Federation Proceedings*, VI (1942), p. 138. (AB 23005).

Jonsson, Finnur. "On the Icelandic colonization of Greenland," *Greenland*, pt. II (1928), 331–361. (AB 8255).

Kirillov, A. A. "Classification of arctic ice and its distribution in the Soviet sector of the Arctic," in Thurston, *Arctic sea ice* (1958), sec. 1, 11–25.

Koch, K. R. "Hardening of the snow through wind," abstract in *SIPRE Bibliography* (1956), X, p. 37.

Koenig, Laurence S. "Discovery of ice islands on U.S.A.F. flights over the Arctic Ocean," *Arctic*, V, No. 2 (1952), 68–75. (AB 23348).

Krylov, M. M. "Soviet ice cellars," *The Polar Record*, VIII, no. 5 (1957).

LaChapelle, Edward. "Ablation studies in the Mint Julep area, southwest Greenland," *Project Mint Julep*, ADTIC Pub. A–104B (1955), pt. II, 51–72. (AB 42959).

Lackey, Earl E. "Alaska water supply," *Geographical Review*, XLI (1954), p. 156.

Lantis, Margaret. "American arctic populations: their survival problems," in Hansen, *Arctic Biology-Biology Colloquium* (1957), 119–131.

Mackay, J. Ross. "Physiography," in Kimble and Good, *Geography of the Northlands* (1955), chap. II, 11–35. (AB 40738).

Manning, Thomas Henry. "Hunting implements and methods of the present-day Eskimos of north-west Hudson Bay, Melville Peninsula, and south-west Baffin Island," *Geographical Journal,* CIII (1944), 137–152. (AB 10882).

Markham, Albert H. "On sledge travelling," *Royal Geographical Society, Proceedings,* XXI (1786), 110–120. (AB 10930).

Mary-Rousselierre, Guy. "A bear hunt on Simpson Peninsula," *Eskimo,* VL (1957), 2–4.

Mason, John Alden. "Notes on the Indians of the Great Slave Lake area," *Yale University publications in Anthropology, no. 34* (1946), 1–46. (AB 11038).

Mutch, James S. "Whaling in Ponds Bay," *Anthropological Papers-Boas Anniversary Volume,* New York (1906), 485–500. (AB 1127).

Nelles, J. H. "Construction and maintenance of the Mint Julep Station," *Project Mint Julep,* ADTIC Pub. A–104A (1955), pt. I, 31–43.

Nesbitt, Paul. "Introduction," *Project Mint Julep,* ADTIC Pub. A–104A (1955), pt. I, v-viii. (AB 42958).

Peschansky, D. S. "Physical and mechanical properties of arctic ice and methods of research," in Thurston, *Arctic sea ice* (1958), sec. 3, 100–104.

Petterssen, Sverre. "Meteorology of the Arctic," *The dynamic North,* 1, no. 2 (1956), pp. xxi + 207. (AB 47336).

Péwé, Troy Lewis. "Permafrost and its effect on life in the North," in Hansen, *Arctic Biology-Biology Colloquium* (1957), 12–26.

Porsild, Morton P. "On 'savssats' a crowding of arctic animals at holes in the ice," *Geographical Review,* VI (1918), 215–228. (AB 13847).

Porsild, Alf. E. "Edible plants of the Arctic," *Arctic,* VI, no. 1 (1953), 15–34. (AB 31461).

Rae, R. W. "Joint arctic weather project," *Arctic,* IV, no. 1 (1951), 18–26. (AB 25334).

———. "The problem of establishing and maintaining weather stations in the Arctic," *Proceedings of the Toronto Meteorological Conference, September 9–15, 1953* (1954), 88–90. (AB 42021).

Rikhter, G. D. "Snow cover, its formation and properties," *SIPRE Trans. 6* (1954), pp. ii + 66. (AB 37065).

Rodahl, Kaare. "Ice islands in the Arctic," *Scientific American,* CXCI, no. 6 (1954), 40–45. (AB 37105).

———. "Vitamin sources in arctic regions," *Norsk Polar-institutt Skrifter,* XCI (1949), 1–64. (AB 14721).

Ross, H. N. "Pre-war experiences of food storage in Spitsbergen," *The Polar Record,* VI, no. 44 (1952), 512–513. (AB 25661).

Saabye, Hans. "Greenland," in Courtauld, *From the ends of the Earth* (1958), 211–222.

Schmitt, R. P. "Project No. 14: Water Supply," *Report on Greenland Operation,* Ft Belvoir, Virginia; U.S. Army Engineer Research and Development Laboratories (1954), 1–32. (AB 48545).

Schwatka, Frederick, "The implements of the igloo," *Science,* old series, IV (1884), 81–85.

Schuster, R. L. "Snow studies," *Project Mint Julep, SIPRE Report 19* (1954), pt. III, 1–11. (AB 37284).

Shackleton, Edward. "A winter in latitude 78° N." *Scottish Geographical Magazine,* LIII (1937), 233–241. (AB 15804)

Sharp, Robert P. "Glaciers in the Arctic," *The dynamic North* I, no. 7 (1956), pp. iv + 44. (AB 47921).

Somov, Mikhaie M. "Observational data of the scientific research drifting stations of 1950–1951," Trans. by Meteorological Society (1956), I, sec. 1, 1–27. (AB 48121).

Stauton, and Rosanoff, "Water for our far north outposts," *Engineering News-Record,* LCX (1958), 39–40.

Stallworthy, H. W. "Winter patrols in the Arctic," *Royal Canadian Mounted Police Quarterly,* II (1934), 17–25. (AB 16683).

Stefansson, Vilhjalmur. "The distribution of human and animal life in western arctic America," *The Geographical Journal,* XL, no. 5 (1913), 449–460.

———. " 'Living off the country,' as a method of arctic exploration," *Geographical Review,* VII, no. 5 (1919), 291–310. (AB 16827).

———. "Natural cold storage," *The dynamic North,* II, no. 13 (1956), pp. iv + 22. (AB 48185).

———. "The North American Arctic," in *Compass of the World* (1945), chap. 16, 215–265.

———. "Northern Alaska in winter," *Bulletin, American Geographical Society,* XLI, no. 10 (1909), 601–610. (AB 16838).

Stoney, George. "Explorations in Alaska," *Proceedings of the United States Naval Institute,* XXV, No. 3 (1899), 533–584.

Sverdrup, Harald U. "Arctic sea ice," *The dynamic North,* I, no. 6 (1956), pp iv + 19. (AB 48303).

Tabata, Tadashi. "Studies on visco-elastic properties of sea ice," in Thurston, *Arctic sea ice* (1958), sec. 3, 139–147.

Takahashi, Toshio and Kudo, Kiyoshi. "Hardness test of snow," *SIPRE Trans. 40* (1955), pp. 7.

Tate, Marguerite G. "Marooned in the clouds," *Atlantic Monthly,* CLXXXI, no. 2 (1948), 34–46.

Taylor, Andrew. "Snow compaction," *SIPRE Report 13* (1953), pp. xxiv + 64.

Untersteiner, N. and Badgley, F. "Preliminary results of thermal budget studies on arctic pack ice during summer and autumn," in Thurston, *Arctic sea ice* (1958), sec. 3, 85–95.

Van de Velde, Franz. "Nanuk," *Eskimo,* XLV (1957), 4–15.

Werenskiold, Werner. "Polar regions," in Brouwer, H. A., *Practical hints to scientific travellers* (The Hague: 1925), Vol. II, 1–150.

Wilimousky, Norman J. "The utilization of fishery resources by the arctic Alaskan Eskimo," *Occasional Papers of the Natural History Museum of Stanford University,* II (1956), 1–8. (AB 48957).

Wilson, J. T. "Geology of northern Canada," *Canadian North* (1946), chap. XIV, 405–424. (AB 48635).

Zubov, Nikolai N. "Arctic ice and the warming of the Arctic," Trans. by E. Hope, (Ottawa: Defence Research Board, 1950), pp. 72. (AB 27622).

Government Publications

Canada, Department of Marine and Fisheries. *Report on the Dominion Government expedition to the northern waters and Arctic Archipelago of the D.G.S. "Arctic" in 1910.* Ottawa, 1911. Pp. 161. (AB 2718).

Canada, Department of Mines and Technical Surveys. Geographical Branch. *Atlas of Canada*. Ottawa, 1957. 110 plates.

———. Geographical Branch. "The Canadian Arctic." *Geography Information Series*. No. 2. Ottawa, 1951. Pp. xiii + 118. (AB 21096).

———. Hydrographic Service. *Pilot of Arctic Canada*. First ed. Vol. I. Ottawa, 1959. Pp. xxiv + 183.

United States, Department of the Air Force. *DEW Line training manual*. Prepared for U.S.A.F. under contract AF 18(600)–572, n.d. Pp. 31 + 189.

———. *"Survival." Air Force Manual*. No. 64–5. Washington, 1945. Pp. 145. (AB 32595).

———. Arctic, Desert, Tropic Information Center. *Glossary of arctic and subarctic terms*. Pub. A–105. Maxwell Air Force Base, 1955. Pp. 90. (AB 42957).

———. Pacific Division, Air Transport Service. *Beetle Project (May 8, 1947–May 15, 1948)*. 1948. Pp. 217.

United States, Department of the Army. "Administration in the Arctic." *Field manual*. FM 31–72. Washington, 1951. Pp. 94.

———. Corps of Engineers. Arctic Construction and Frost Effects Laboratory. *Depth of snow cover in the Northern Hemisphere*. Boston, 1954. Pp. 4 + 13 tables + 38 plates. (AB 48539).

United States, Department of the Navy. Bureau of Yards and Docks. "Improved ice harvesting." *Military Engineer*, XLI, 1949. Pp. 290–291. (AB 24346).

———. Hydrographic Office. "Arctic ice and its drift into the North Atlantic Ocean." *Pilot Chart*. No. 130. Fourteenth ed. Washington, 1955. 1 sheet. (AB 43008).

———. Hydrographic Office. *Ice atlas of the Northern Hemisphere*. Pub. No. 550. Washington, 1946. Pp. 106.

———. Hydrographic Office. *Oceanographic atlas of the polar seas. Part II, Arctic*. Pub. No. 705. Washington 1958. Pp. 145.

United States, Quartermaster Corps. *Prevention of freezing of water in canteens*, Report No. 4603. Lawrence, Mass.: Research and Development Branch, 1946. Pp. 11.

Unpublished Material

Bobbit, Ottis C. *A dog sled trip—Point Hope to Point Barrow, Alaska—November 9 to December 7, 1946*. Photostat copy at ADTIC, Maxwell Air Force Base, 1947. Pp. 61.

Ekblaw, Walter Elmer. *The Polar Eskimo*: their land and life. Doctoral dissertation submitted to Clark University, 1926.

Hare, Frederick K. *The climate of the eastern Canadian Arctic and Sub-arctic, and its influence on accessibility*. Doctoral dissertation submitted to the University of Montreal, 1950. Pp. 440. (AB 29551).

Hobbs, William H. "Cooking devices for arctic sledging use." *Encyclopedia Arctica*. Stefansson Library, Dartmouth University, n.d. Pp. 4.

Ridge, F. Gerald *General principles of planning of sub-arctic settlements*. Doctoral dissertation submitted to McGill University, 1953. Pp. 569. (AB 37038).

Seeyle Stevenson Value & Knecht, Consulting engineers. *Report on water supply for the DEW Line*. New York, 1956. Pp. 19 + 195.

Siple, Paul A. *Adaptations of the explorer to the climate of Antarctica*. Doctoral dissertation submitted to Clark University, 1939. Pp. 525.

Sonnenfeld, Joseph. *Changes in subsistence economy among Point Barrow Eskimo.* Doctoral dissertation submitted to Johns Hopkins University, 1957. Pp. 589.

Stefansson, Vilhjalmur. *Instructor's manual for the Arctic.* Typed copy at ADTIC, Maxwell Air Force Base, n.d. Pp. 94.

Teal, John J., Jr. "Patterns of discrimination in the Arctic," *Encyclopedia Arctica.* Stefansson Library, Dartmouth College, n.d. Pp. 27.

Wonders, William C. *The climate of the Canadian Arctic Archpelago,* Doctoral dissertation submitted to the University of Toronto, 1951.

Appendix A

LIST OF ESKIMO GROUPS*

1. Chugachigmiut
2. Kaniagmiut
3. Aleut
4. Ogulmiut
5. Togpagamiut
6. Nushagamiut
7. Kuskokwagmiut
8. Nunivagmiut
9. Kaialigamiut
10. Magemiut
11. Ikogmiut
12. Unaligmiut
13. St. Lawrence Island Eskimos
14. Kaviagmiut
15. Kinugmiut
16. Malemiut
17. Nunatagmiut
18. Noatagmiut
19. Oturkagmiut
20. Killirmiut
21. Kopagmiut
22. Kugmiut
23. Utkiavigmiut
24. Point Barrow Eskimos
25. Mackenzie Eskimo
26. Kupugmiut
27. Nuvorugmiut
28. Kittegaryumiut
29. Copper Eskimo
30. Ahagmiut
31. Padlermiut
32. Harvaqtormiut
33. Qaermiut
34. Caribou Eskimo
35. Utkuhighalingmiut
36. Ugyuligmiut
37. Netsilirmiut
38. Arvertormiut
39. Kungmiut
40. Arviligjuarmiut
41. Nuajarmiut
42. Sagdlirmiut
43. Nagssugtormiut
44. Aivilirmiut
45. Iglulrmiut
46. Aggomiut
47. Akudnirmiut
48. Okomiut
49. Nugumiut
50. Akuliarmiut
51. Nuvugmiut
52. Tahagmiut
53. Itivimiut
54. Kigiktagmiut
55. Ungavamiut
56. Koksoakmiut
57. Kidlinungmiut
58. Sukinninmiut
59. Kongithlushuamiut
60. Okagamiut
61. Nunengmiut
62. Avitimiut
63. Aivitimiut
64. Netcetumiut
65. Putlavamiut
66. East Greenland Eskimo
67. Ammassalingmiut
68. Kalatdlitmiut
69. Quavaitmiut
70. Akunermiut
71. Kangiamiut
72. Qeqertarsuarmiut
73. Avangnamiut
74. West Greenland Eskimo
75. Smith Sound (Polar Eskimo)

*Driver, *et al.*, "Indian Tribes of North America, Memoir 9," *Indiana University Publications in Anthropology and Linguistics*, (Indiana University, 1953), Pp. 30. See Figure 13 for location of these groups by numbers.

Appendix B

PER CAPITA WATER REQUIREMENTS—GALLONS PER DAY*

Size and character of group	*D*	*C*	*B*	*L*	*W*	*S*	*O*	*T*[1]
1. Temporary, large & small.								
Melted snow.	1	1						2
2. Permanent, small.								
Melted snow & ice.	1	1	10	3				15
3. Permanent, small.								
Winter, melted snow & ice.	1	1	10	3				15
Summer, Haul water.	1	1	10	3				15
4. Permanent, small.								
Winter, melted snow & ice.	— 2—		10	3				15
Summer, wells.	—10—		20	5				35
5. Permanent, small.								
Wells, river or lake pumped.	—10—		25	20	10	5	5	75
6. Permanent, large.								
Wells or surface pumped.	—10—		25	15	20	20	10	100

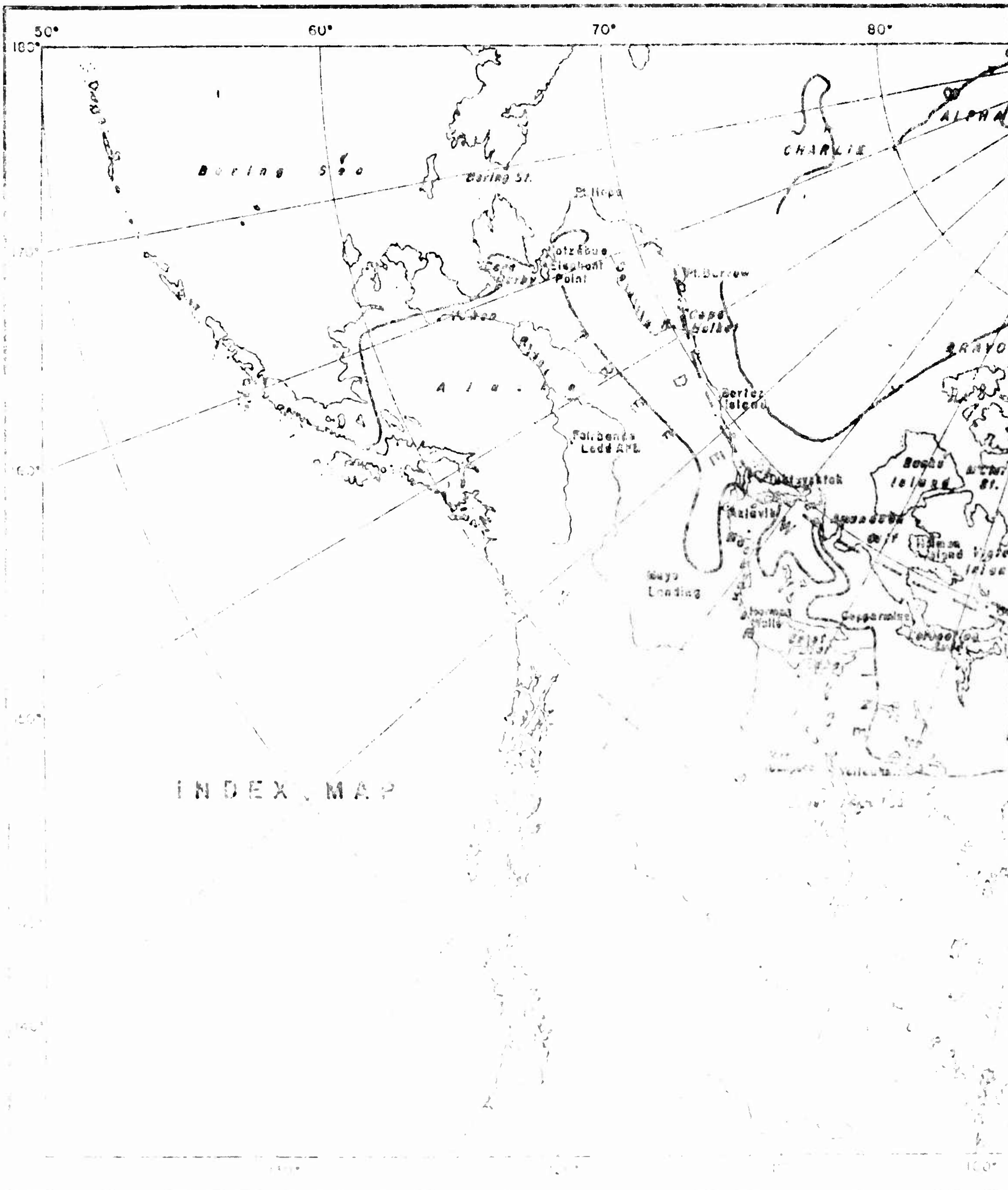
KEY

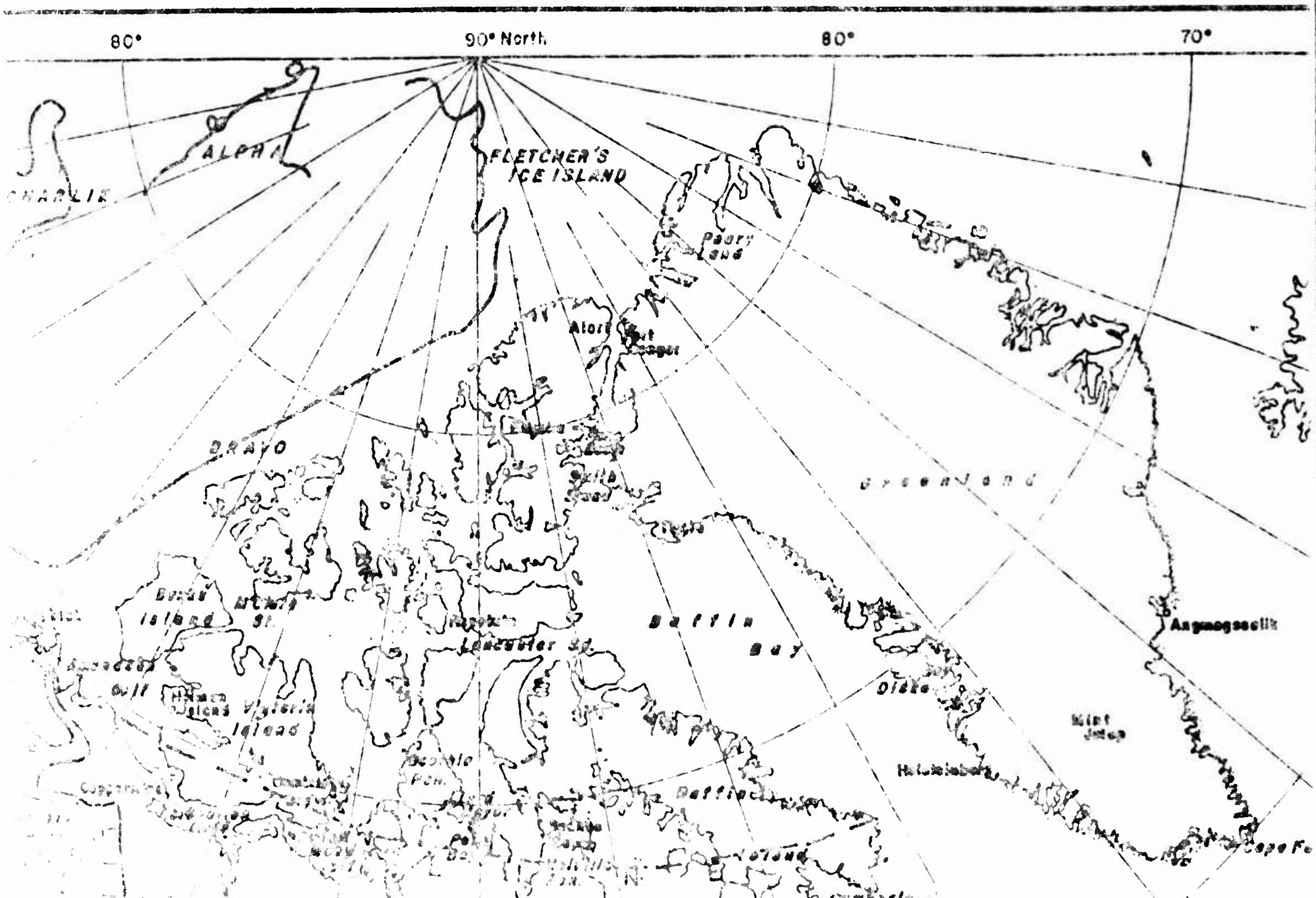
D—Drinking water
C—Cooking water
B—Bathing & washing
L—Laundry water
W—Water toilet
S—Steam
O—Other
T—Total

[1]These values do not include water used in allowing taps to flow continuously to prevent freezing.

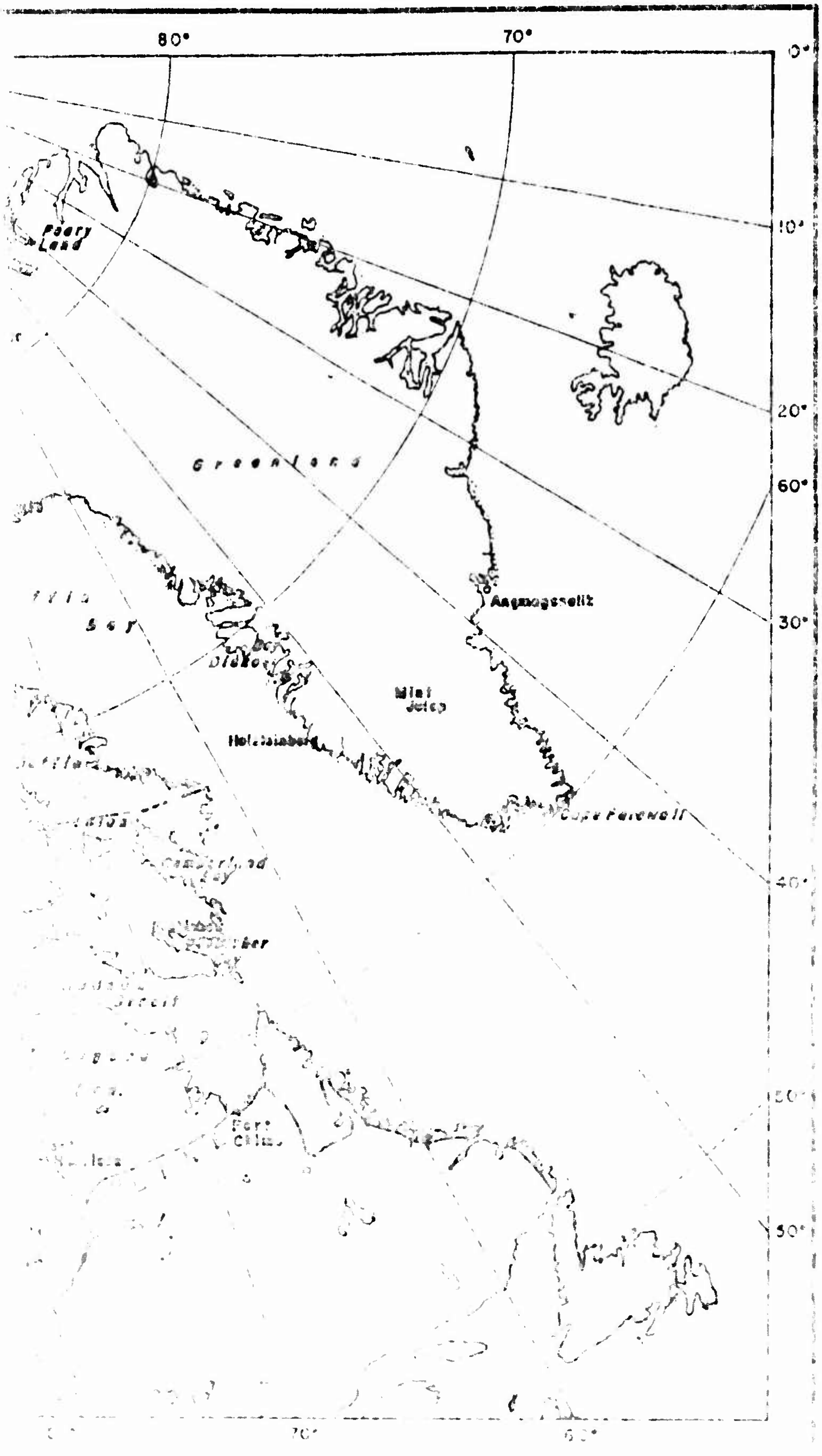
*Hostrup, Lyons & Associates, op. cit., pp 22-23.

AIR FORCE—GAFB, ALA. (611879) 500


50°
60°
70°
80°
180°
170°
160°
Bering Sea
Bering St.
CHARLIE
ALPHA
BRAVO
Kotzebue
Elephant Point
Pt. Barrow
Cape Halkett
Barter Island
Alaska
Fairbanks Ladd AFB
Aklavik
Banks Island
Mayo Landing
Coppermine
INDEX MAP


80°
90° North
80°
70°
ALPHA
FLETCHER'S ICE ISLAND
BRAVO
Greenland
Baffin Bay
Lancaster Sd.
Angmagssalik
Victoria Island
Cumberland Bay
Coral Harbour

793


80°
70°
10°
20°
60°
30°
40°
50°
Peary Land
Greenland
Angmagssalik
Mint Julep
Holsteinsborg
Cape Farewell
70°
60°