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# Adaptive Responses of Paleoindians to Cold Stress on the Periglacial Northern Great Plains

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# 2. Adaptive Responses of Paleoindians to Cold Stress on the Periglacial Northern Great Plains

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*Abstract:* Archaeologists' cumulative knowledge about Paleoindians has grown substantially during the past two decades, and accomplishments have been impressive. I find, however, that much of the research regarding the archaeology of the Paleoindian period is primarily descriptive and highly particularistic. In this essay, I propose that our understanding of Paleoindian artifact assemblages, associated ecofactual materials, and human remains can be more meaningful within a broader biophysical context. We must ask how the archaeological record of the Late Glacial period might provide paleoanthropologists with greater insights into early hunter-gatherer anatomy, physiology, diet, health, and behavior. I propose that our understanding of hunter-gatherer life during the Late Glacial period may now be further enhanced by redirecting our attention toward several important technological responses that Paleoindians most probably made to cold stress and thermoregulation, including clothing, housing, and fire technology.

For nearly a century, studies of Paleoindians focused primarily upon the collection and description of distinctive chipped-stone tools and the bones of extinct animals found in "kill" sites, camp locations, and tool caches throughout the Americas. The archaeological folklore generated to account for those remains described bands of voracious human carnivores who surged across the Beringian "causeway" and streamed through a narrow "ice-free" corridor in west-central Canada. While en route to Tierra del Fuego, these *r*-selected, well-armed hunters and their families killed and devoured teeming herds of giant, yet docile, mammoth, mastodon, and bison, as well as more solitary glyptodon and giant ground sloth. Amazingly, many archaeologists apparently still believe that the earliest Americans colonized nearly 30% of the

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earth's land surface and exterminated more than 35 genera of Pleistocene fauna in North America alone within less than 1,200 years.

Within the past two decades, archaeologists have discovered or rediscovered many significant Paleoindian sites, as well as human remains, throughout the Americas (Figure 2-1). Recent excavations and reanalyses of artifact and faunal assemblages have generated a great deal of new information about the earliest hunter-gatherers in the Americas. In addition, investigators now possess an array of new technologies and analytical methods that include blood-residue studies, recovery of DNA from animal and human hair, mitochondrial DNA (mtDNA) analyses of extant Native American populations, and improved dating methods (i.e., accelerator mass spectrometry [AMS] and optical stimulated luminescence [OSL]). On the other hand, many very significant questions about Paleoindian anatomy, physiology, diet, health, and behavior have not been addressed.

Few archaeologists in the New World have given much attention to the ecological constraints of late-glacial winters. The adaptive strategies of hunter-gatherers of Eurasia and North America within the periglacial region were, no doubt, shaped by factors related to thermoregulation (e.g., Geist 1978, 1999; Guthrie 1990a, 1990b, 1995, 1996). In this chapter, I will focus upon several important technological responses that Paleoindians most probably made to cold stress, including clothing, housing, and fire technology. Late-glacial hunter-gatherers may have developed an adaptive suite, or "a unique coadapted complex of physiological, behavioral, and ecological traits, whose functions complement[ed] one another and enhance[d] . . . [their] reproductive success" (Pianka 1983:95). Such an adaptive suite or optimal design should then be reflected in the archaeological record of Paleoindians.

## Late-Glacial Environments in North America

During the past million years, the earth has experienced a series of periodic fluctuations from glacial to interglacial conditions that were causally linked to cyclical changes in its orbital geometry and axial tilt and "wobble"(Berger 1978a, 1978b; Imbrie and Imbrie 1979; Kutzbach and Webb 1991, 1993). Recent models have also implicated shifts in the North Atlantic Deep Water (NADW) thermohaline conveyor system that serves to distribute heat from the equator toward the Arctic (Broecker 1999; Kennett 1990; Seidov and Haupt 1997). Between 120,000 and 115,000 years ago, mean summer temperature declined 3–4°C so that less winter snowfall and ice melted (Dawson 1992:62; Hughes 1996; Miller and de Vernal 1992).

Winter sea ice expanded throughout the High Arctic and created a high-albedo white hole that locked up all available precipitation (Hughes 1996:449). Ice sheets expanded to cover more than 16 million km$^2$ (6,177,630 mi$^2$) with 34–43 million km$^3$ (8.2–10.4 million mi$^3$) of ice between 25,000 and 21,000 radiocarbon years ago ($^{14}$C B.P.; Dawson 1992; Hughes 1996). Ice domes over Hudson Bay and Greenland may have ranged from 1,650 to 4,000 m (5,412–13,123.4 ft) in thickness (Hughes 1996:460; Kutzbach and Ruddiman

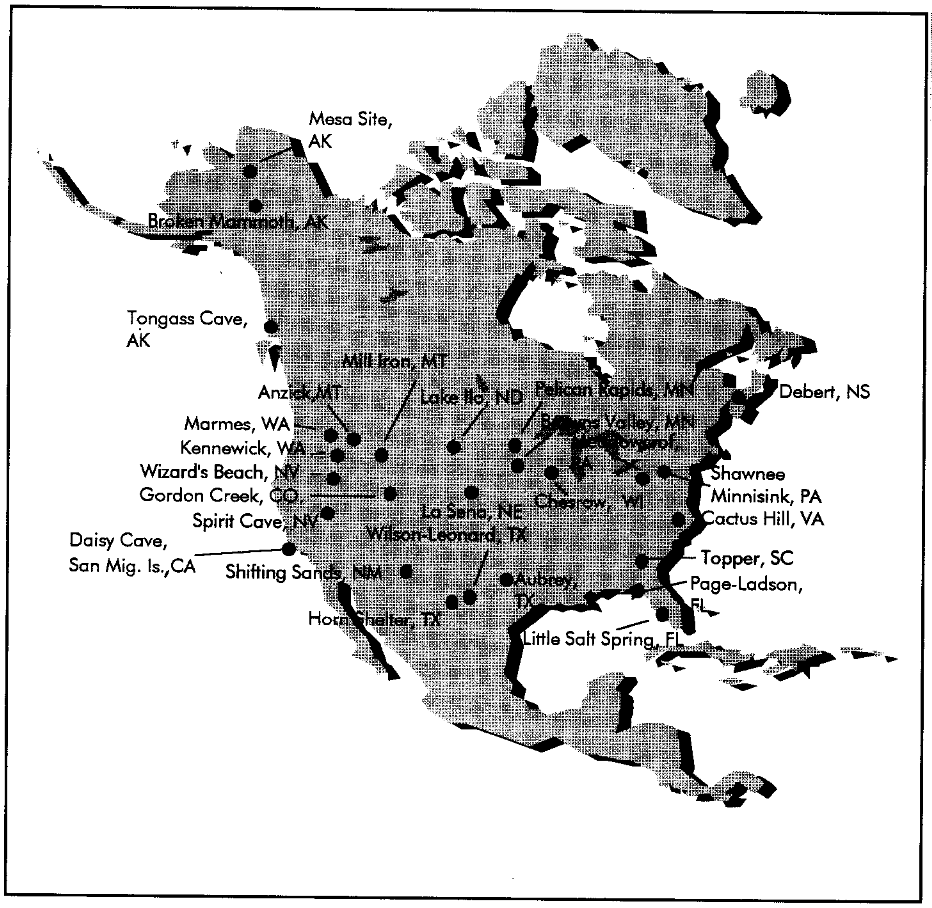


**Figure 2-1.** *Location of select Paleoindian sites in North America.*

1993:16; Peltier 1994:200). Between 21,000 and 17,000 $^{14}C$ B.P., the southern margin of the Laurentide ice sheet coincided roughly with the present-day Canadian-United States border from the Pacific Northwest to eastern Montana where it then pushed 1,000 km southward to cover northeastern North Dakota and South Dakota, Minnesota, north-central Iowa, Michigan, northern Illinois, Indiana, Ohio, and the Northeast (Denton and Hughes 1981:Figure 2-4).

At 18,000 $^{14}C$ B.P., the jet stream flowed along both the northern and southern edges of the Canadian ice sheets. An intense high-pressure system caused winds to rotate clockwise around the Laurentide ice sheet (see Thompson et al. 1993:Figure 18.18). Strong, cold easterly winds moved across the continent between the southern branch of the jet stream and the southern edge of the ice mass. By 12,000 $^{14}C$ B.P., the prevailing surface winds across the northern Plains shifted from easterlies to westerlies (Thompson et al. 1993:501).

Frigid air masses warmed as they descended from the domes of glacial ice. Fierce katabatic winds rushed outward from ice domes at speeds around 100

to 150 km (62–93 mi) per hour (Pielou 1991:26). Tremendous dust storms were generated when those winds scoured rock flour and ice particles from end moraines and dry stream and lake beds. In addition, vast cloud belts were created far beyond the margins of the continental ice sheets (Hughes 1996:452–453).

Due to the area, height, and high reflectivity of the Laurentide ice sheet, atmospheric circulation patterns increased both the seasonality and the continentality of the Northern Hemisphere. During the Late Glacial Maximum (LGM), summers were warmer, winters were colder, and mean annual temperatures were similar to the present (Kutzbach and Webb 1993:8). Predicted mean July temperatures were 2–6°C (3.6–10.8°F) lower over land and perhaps 20–40°C (36–72°F) lower over the elevated ice sheets due to the albedo effect (Webb et al. 1993:517). Tremendous amounts of moisture evaporated from immense proglacial lakes, like Lake Agassiz, that surrounded the southern margins of the glaciers. For the continental interior east of the Rocky Mountains, precipitation was scant due to "adiabatically warmed air" that descended from the vast ice sheets along the lee side of the mountain range (Wright 1987:486).

Based upon predictions of temperature anomalies (Table 2-1) generated by the Cooperative Holocene Mapping Project (COHMAP), we find that in western North Dakota, for example, at 18,000 $^{14}$C B.P., the mean July temperature was 2.73°C, or 18.37°C below the present-day mean of 21.10°C (Table 2-2; see Tables 2-1 to 2-4 for °C to °F conversions). More importantly, estimated mean January temperature was -22.68°C, or almost 11°C below the present-day mean of -12.10°C (Table 2-2; Figure 2-2).

Bryson and Bryson (1996) have predicted that mean annual temperature for western North Dakota during the late Pleistocene (ca. 14,000 $^{14}$C B.P.) was about -5°C, or 10.33°C colder than present (5.33°C; Table 2-3). Mean coldest-month temperature during the late Pleistocene (12,000 $^{14}$C B.P.) was -18.24°C, and present-day mean coldest-month temperature is -12.10°C (Table 2-2). Thus, during the Late Glacial period (18,000–12,000 $^{14}$C B.P.), coldest-month temperatures ranged from 11.00°C to 6.14°C colder than present.

During the Younger Dryas event (11,000–10,000 $^{14}$C B.P.), mean coldest-month temperatures ranged from -20°C to -17.5°C, or from 7.9°C to 5.4°C below present-day mean January temperature (Tables 2-3, 2-4). Mean coldest-month temperatures do not reflect the low temperature extremes that may have characterized late-glacial winters.

Interestingly, late-glacial winters were apparently quite dry. Guthrie (1982, 1990a) argues that large mammals of the Mammoth Steppe were not well adapted to heavy snow cover. He (1982:313) states, "Mammoth had no obvious means of penetrating winter snow (the striations on tusks do not indicate wear from snow shoveling) for the quantity of necessary food and so probably used windblown winter ranges." Guthrie (1982:314) also points out that Pleistocene horses, sheep, and to some extent steppe bison were adversely affected by deep snow cover.[1]

We must, therefore, consider the "bottleneck," or array of ecological constraints, imposed by Late Glacial period winters upon human groups in the

**Table 2-1.** *Late Pleistocene-Early Holocene Temperature Anomalies or Departures from Modern Normals for the Northern and Central Regions of the Western United States*

| Date ($^{14}$C B.P.) | Northern January (°C) | Northern July (°C) | Northern Annual (°C) | Central January (°C) | Central July (°C) | Central Annual (°C) |
|---|---|---|---|---|---|---|
| 18,000 | -10.58 | -18.37 | -14.80 | -8.31 | -3.83 | -6.30 |
| 12,000 | -6.14 | -8.67 | -8.37 | -5.15 | -2.22 | -4.55 |
| 9000 | +0.73 | +2.24 | +0.61 | +0.34 | +1.15 | -0.13 |
| 6000 | -0.81 | +2.33 | +0.31 | -0.16 | +1.04 | +0.07 |

*Source:* Thompson et al. (1993:Figure 18.16).

**Table 2-2.** *Late Pleistocene-Early Holocene Temperature Estimates for Western North Dakota*

| Date ($^{14}$C B.P.) | Northern January (°C/°F) | Northern July (°C/°F) | Northern Annual (°C/°F) |
|---|---|---|---|
| 18,000 | -22.68/-8.82 | 2.73/36.91 | -10.8/12.56 |
| 12,000 | -18.24/-0.83 | 12.43/54.37 | -4.37/24.13 |
| 9,000 | -11.37/11.53 | 23.34/74.01 | 4.61/40.30 |
| 6,000 | -12.91/8.76 | 23.33/73.99 | 4.31/39.76 |
| Present | -12.1/10.22[a] | 21.1/69.98[a] | 4.0/39.20[a] |

*Note:* Temperature estimates are based on the northern region departures in Table 2–1.
[a]Based on temperature data for Dickinson, North Dakota (1892–1930).

Western Hemisphere. These constraints resulted from extremely cold and arid winter seasons characterized by very low winter air temperatures, high-velocity winds, severe windchill, lack of appreciable snow cover, and extreme aridity. The remaining portion of this chapter will focus upon cold stress and several important technological responses that Late Glacial period hunter-gatherers may have made in northern periglacial environments, particularly in the northern Great Plains.

## Human Responses to Cold Stress

There are a number of responses that humans can make to cold stress (Folk 1974; Linardini 1981; Newman 1956; So 1980; Steegmann 1975; Szathmary 1984). Humans are homeothermic, as well as endothermic, organ-

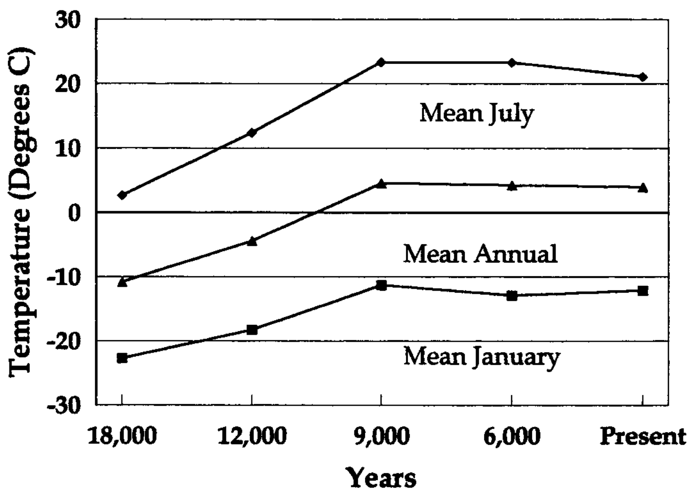


**Figure 2-2.** *Late Pleistocene-Early Holocene temperature estimates for western North Dakota (based on Thompson et al. 1993: Figure 18.16).*

isms that "can maintain a relatively constant body temperature which is independent of the environmental temperature," and they can produce and regulate their own body heat (Folk 1974:90). Nonhibernating homeotherms, including humans, must "alternate between decreasing heat loss rates and increasing heat production rates" (Steegmann et al. 1983:322). The *zone of thermal neutrality* for the human body lies between 25°C and 27°C (77–80°F; Folk 1974:112). If the temperature of the external environment falls outside this range, then physiological, behavioral, and/or technological responses must be made in order to lose or generate heat (Figure 2-3).

Human body heat is lost by means of radiation, conduction, convection, and evaporation. In order to increase heat production or to limit heat loss, humans depend upon a range of morphological responses (i.e., genetic and nongenetic changes in body shape, mass, and surface:mass ratios). Physiological adjustments to cold stress include shivering thermogenesis, nonshivering thermogenesis, cyclical vasodialation and vasoconstriction, dietary-induced thermogenesis (DIT), and limited accumulation and/or redistribution of adipose tissue. In addition, behavioral responses to cold stress include increased activity levels, shifts in posture, and minimization of windchill. Technological and behavioral adjustments may involve use of external heat sources such as solar radiation, fire, and animal/human body heat, clothing, and shelters.

## Technological Adaptive Responses

Once we become more familiar with the causal connections between cold stress and human morphology, physiology, and behavior, we can

**Table 2-3.** *Modeled Mean Annual Temperature and Precipitation for Western North Dakota*

| *Date* ($^{14}$C B.P.) | *Mean Annual Temperature* (°C/°F) | *Mean Annual Precipitation* (mm) |
| --- | --- | --- |
| 14,000 | -5/23 | 460 |
| 13,000 | -3.5/25.7 | 453 |
| 12,000 | -4.5/23.9 | 463 |
| 11,000 | 1/33.8 | 440 |
| 10,500 | 0.2/32.4 | 450 |
| 10,000 | 1/33.8 | 385 |
| Present | 5.33/39.8 | 432 |

*Source:* Bryson and Bryson (1996).

begin to identify a range of technological responses that increase heat within and/or decrease heat loss from the human body. The following discussion examines certain aspects of ethnographically documented aspects of clothing, shelter, and fuel technology that may prove to be relevant to our studies of hunter-gatherers during the Late Glacial period (18,000–10,000 $^{14}$C B.P.).

### *Clothing*

We can anticipate that winter clothing would have been essential to Paleoindian adaptations in the Western Hemisphere—especially in high-latitude and high-altitude settings. There are a number of excellent studies of winter skin clothing used by native peoples—particularly in the circumpolar region—that provide valuable information regarding insulative properties, activity constraints, raw-material requirements, and archaeological correlates of hunter-gatherer clothing (e.g., Ammitzbøll et al. 1991; Bahnson 1997; Buijs 1997; Buijs and Oosten 1997; Hall et al. 1994; Hatt 1969 [1914]; Issenman 1985, 1997; Oakes 1991; Oakes and Riewe 1992, 1995; Stefánsson 1955; Stenton 1991).

#### Insulation Properties

Humans can increase the insulative properties of the warm air layer surrounding their bodies by adding layers of plant fibers, bird feathers, and animal skins and fur.[2] A comparison of the insulation values and thicknesses of various animal furs is provided in Figure 2-4. Inuit skin clothing, for example, provides ample protection against outside air temperatures of -40°C to -60°C (-40– -76°F; Stenton 1991:10). The insulation properties of an animal's fur or human clothing are reduced when the body is set into motion or wind speeds increase.

**Table 2-4.** *Modeled Mean Coldest and Warmest Months in Western North Dakota*

| *Date ($^{14}C$ B.P.)* | *Mean Warmest Month (°C/°F)* | *Mean Coldest Month (°C/°F)* |
|---|---|---|
| 11,300 | 18/64 | -20/-4 |
| 11,100 | 23/73.4 | -18/-0.4 |
| 10,900 | 21/69.8 | -19.5/-3.1 |
| 10,700 | 24/75.2 | -18/-0.4 |
| 10,500 | 19/66.2 | -20/-4 |
| 10,100 | 25/77 | -17.5/0.5 |
| Present | 21.1/70 | -12.1/10.22 |

*Source:* Bryson and Bryson (1996).

## Clothing and Adjustment of Activity Levels

In extremely cold environments, well-clothed humans must confront two very significant problems: heat stress and dehydration. Once people wearing layers of well-insulated clothing become very active, they may experience several adverse effects, including heat stress, excessive perspiration and water loss, and loss of insulation due to perspiration.[3, 4] Shephard (1980:330–331) points out that rigorous outdoor activities in the circumpolar region result in "excessive sweating [that] rapidly degrades the insulating properties of clothing."

Eskimo and northern Indian clothing was designed to provide ventilation and evaporation of body moisture during strenuous exercise (Buijs 1997; Folk 1974; Issenman 1985; Steegmann et al. 1983; Stefánsson 1955; Stenton 1991). Eskimo clothing made use of the "chimney effect" that drew in air below the knees, around the waist, and up through the sleeves and then allowed the warm, moist air to vent around the neck and face (Folk 1974:Figure 5-55). Clothing serves to trap a layer of still, warm air around the body. Relatively loose-fitting clothing worn in layers served this purpose. Eskimo winter clothing incorporated a number of "ventilation areas, gaps, and drawstrings" that enabled the wearer to remove outer layers quickly in order to cool the body and to "shake out" frozen perspiration (Folk 1974:196).

Various kinds of boots and winter moccasins were worn to reduce heat loss via conduction or contact with snow, ice, and frozen ground. In extremely cold regions, winter boots did not have to be waterproof because the snow remained dry (Steegmann et al. 1983:326). Foot gear also served to trap pockets of warm air around the foot and to prevent conductive heat loss. Each adult Inuit required three pairs of winter and summer boots (Issenman 1985:105). Special sewing stitches, *ilujjinig,* were used when making boots. The stitch penetrated one skin and one-half of the second skin; it was then drawn

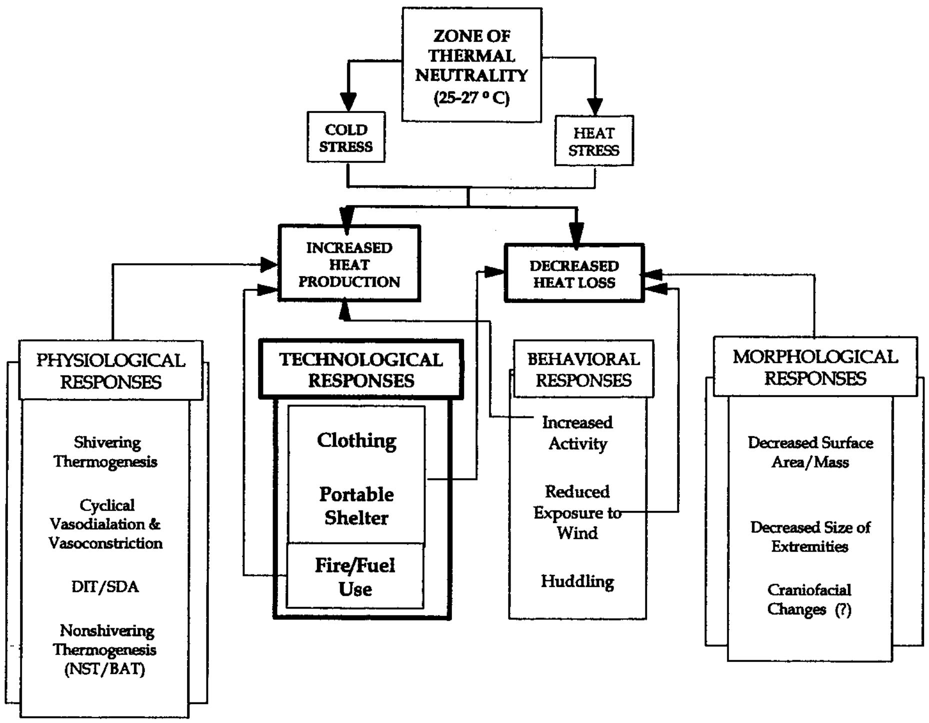


**Figure 2-3.** *Adaptive responses of humans to cold stress.*

back through the first skin. According to Issenman, sinew "thread" expanded to fill the holes made through the skins, thereby providing watertight boots (1985:104). Interestingly, Issenman (1985:106) also states, "Repairs [to boots] are made immediately after the hunt, or if necessary on the trail, for which the hunter will carry his own sewing kit."

Anthropologists have observed a marked contrast between forest and tundra hunters with respect to winter-activity patterns. The contrast involves winter-activity and mobility patterns, clothing use, fuel availability, and water consumption. Steegmann and colleagues (1983:327) point out that tundra hunters pay particular attention to their activity levels, continually adjust their clothing to reduce perspiration, and stop infrequently. Forest hunters, on the other hand, move relatively quickly over the landscape, engage in strenuous activities (e.g., walking through deep snow), and stop frequently to build wood fires, to dry their clothing, and to make hot tea in order to rehydrate themselves. Steegmann and his associates (1983:328) state, "Fire is a constant companion and is used with clothing in cold adaptation: its importance is probably more acute here than in any other anthropological setting."

## Raw Materials for Clothing

Throughout the Arctic, caribou or reindeer skin was most preferred for winter clothing, including inner coats, outer parkas, inner and outer

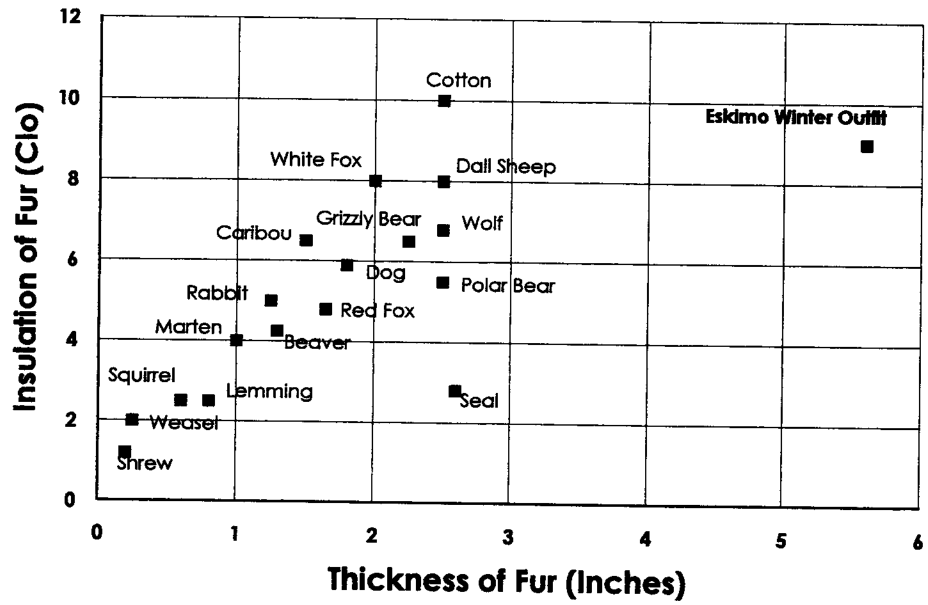


**Figure 2-4.** *Insulation values for various mammal fur and Eskimo winter outfits (interpolated data from Folk 1974:Figure 5-6).*

pants, and boots. The Eskimo preferred caribou skins for their clothing because they provided excellent insulation, they were very durable, and they were lightweight (a complete winter outfit weighed 3.0–4.5 kg (Issenman 1984:29; Riewe 1975:26; Stefánsson 1955). A number of researchers have emphasized the distinctive insulative properties of caribou and reindeer fur (e.g., Bahnson 1997; Hatt 1969 [1914]; Issenman 1985; Stenton 1989, 1991; Watkins 1984). Caribou fur provides extremely effective insulation because both the hollow guard hairs and the spaces between inner and outer layers of hair serve to trap air (Issenman 1985:103; Stenton 1991:6). The skins of other terrestrial mammals including domestic dog, wolf, wolverine, Arctic hare, Arctic ground squirrel, muskrat, polar bear, and musk ox were used for ruffs, trim, and mittens (Oakes 1991:104).

Stenton (1991) points out that in the Arctic caribou skins to be used for clothing must be obtained in the early fall. Caribou shed both inner and outer hair layers in spring and summer. Warble fly larvae emerge from numerous "breathing holes" that they have cut through the caribou skins in late May and June (Arima 1984:449). As Stenton (1991:6) states, "These parasites can drastically reduce the quality of the skin for human use, with exit holes making the skin worthless for clothing . . . until about early August."

Caribou-skin clothing for winter consisted of an outer and an inner layer (Stenton 1991:7). The inner garment was fashioned so that the pelage, or fur, was on the inside close to the wearer's body. The outer garment was made so that the fur was on the outside where its undercoat and guard hairs trapped

warm air to serve as insulation. The hood on winter clothing is particularly important for maintaining an "insulation envelope." The ruff of wolverine, dog, or wolf fur surrounds the face and traps a layer of warm air (Issenman 1985:104; Riewe 1975:29).

## Clothing Replacement Rates and Skin Requirements

Eskimo skin clothing had a relatively short use life. An adult usually possessed only one complete winter outfit that could be worn for one season. Stenton (1991:9) discusses the limitations of caribou-skin clothing in relation to the breakdown of the guard hairs and corresponding loss of insulation value. Stefánsson (1955:38) also mentions that fur and leather tend to decay due to moisture damage. As a result of these factors, Eskimo winter clothing may have lasted up to a maximum of three years, but it was usually replaced each year (Stenton 1991:9). In some cases, winter fur parkas and undergarments were shorn, recycled, and worn during the summer (Issenman 1985:105).

The demand for animal skins or hides for clothing, bedding, and shelter must be incorporated into current models of optimal foraging and hunting strategies (see Keene 1981:181). In some cases, animals may have been killed primarily for their hides instead of for food. This is not to suggest, however, that the meat would not have been consumed. Hudson Bay Eskimo, for example, procured caribou in late October when the young possessed thick coats, the females were thin, and the males contained large deposits of back fat (Turner 1894:276). Butchering, fat stripping, and hide processing would generally have to be carried out simultaneously. This situation might pose very significant labor constraints upon hunter-gatherer groups. Table 2-5 presents information regarding the animal-skin requirements for annual or winter-season clothing.[5]

The procurement of adequate numbers of quality animal skins was critical. Hunting strategies were conditioned by the condition of the prey animals. Hides for the winter overparka, for example, were taken from animals in the early fall when the fur was 4–5 cm (1.5–1.75 in) thick (Oakes 1991:102). It is interesting to note that the Netsilik established special camps for the primary purpose of making winter clothing and instituted strict taboos against hunting at that time during the fall (Balikci 1970:55).

## Skin Preparation

The preparation of caribou hides for tents, sleeping bags, boots, and winter clothing is arduous. Animal hides, or skins, must be carefully prepared prior to the manufacture of clothing. Once the skin has been carefully removed from the carcass, it must be scraped several times in order to remove fat, tissue, and blood. Certain hides were dried, smoked, and/or treated with chemicals to prevent putrefaction.[6] Certain skins were depilated prior to making clothing; the hair was cut or shaved, and then the skins were soaked in water or urine to hasten rotting of the epidermis (Hatt 1969:14 [1914]). Animal skins, then, are more durable if the corium is treated with animal fats (e.g., animal brains and bone grease), plants (e.g., tannins from oak or alder

**Table 2-5.** *Animal-Skin Requirements for Clothing in High-Latitude Settings*

| *Group* | *Animal Skin* | *Skin Requirement (number/person/yr.)* | *Reference* |
|---|---|---|---|
| Huron (Ontario) | White-tailed Deer | 3.5 | Gramly (1977:602) |
| Caribou Eskimo | Caribou | 6–8 | Arima (1984:449) |
| Caribou Eskimo | Caribou | 8 | Stenton (1989:89) |
| Tarramiut (Inuit of Quebec) | Caribou | 8 (3 adults, 2 children, 40 skins for winter clothing) | Saladin d'Anglure (1984:491) |
| Quebec Inuit | Caribou | 2 (60 skins for a band of 30 people) | Saladin d'Anglure (1984:489) |
| Caribou Eskimo | Caribou | 12 | Banfield (1954) |

bark), minerals (alum, white clay, chalk, wood ash, and red ocher), and smoke (aldehyde; see Hatt 1969:14–20 [1914]).

A single dried caribou skin may require from eight to nine hours of scraping and softening (Emily Alerk, personal communication [1992] in Hall et al. 1994:18; Oakes 1991:105). The contemporary Copper Inuit applied baking flour, powder, or soda to an animal skin during the final scraping to serve as a desiccant and "a fine abradant, making the final scraping easier to complete" (Oakes 1991:111). The Caribou Inuit did not use brain, liver, fat, or smoke to prepare the hide, probably because they were generally not depilated. Hatt (1969:19 [1914]) also states that "[d]epilated skins are smoked most frequently—in all probability skins with hair do not withstand the heating as well."

### Skin Tanning and Tawing and Red Ocher

In North America, red ocher has been observed in Paleoindian artifact caches (e.g., Fenn and Simon), human burials (e.g., Anzick "Cache," Montana; Brown's Valley, Minnesota; Gordon Creek, Colorado), and residential contexts (e.g., Agate Basin, Hanson, Cattle Guard, Lindenmeier; Roper 1991: Table 1, 1996; Tankersley et al. 1995).[7] Red ocher also occurs at a number of Chatelperonian, Gravetian, and Magdalenian residential locations (Ighilahriz 1996; Klein1969; Philibert 1994).

Various uses for ocher have been described in the ethnographic literature for the Caribou Eskimo (Birket-Smith 1929), the Tuchone in the southern Yukon (McClellan 1981), the Ona and the Tehuelche (Cooper 1946a, 1946b), the Himba (Bannister and Johnson 1990), and the Nuba (Jacobsohn 1995: 175–176). Uses include mineral-based paints and fat-based waterproofing mixtures for skin clothing, clothing bags, hide tents, and skin covers for kayaks. Ocher was used by the Arunta in central Australia to protect wooden implements against termites and ants (Spencer and Gillen 1968). Ocher was also

added to fat-based wind screen and sunscreen for human faces and bodies. It is also possible that ocher was used as an abrasive powder during hide scraping (see Oakes 1991:111), and it may have been applied to skin clothing as a desiccant and/or a pesticide to deal with lice, mites, fleas, or other pests.

Roper (1991, 1996) and Tankersley and colleagues (1995) probably place undue emphasis upon the "symbolic" dimension of the use of red ocher among Upper Paleolithic and Paleoindian peoples. Roper (1991:296) does mention, however, that red ocher may have been used in the tanning and/or tawing of skins. In the historic past, hides, or skins, have been treated with aluminum salts, chromium, and other substances. Those chemical substances transform animal skins into leather—an animal product that is resistant to wear and to rapid destruction by microorganisms (Brown and King 1995). Although tawing makes skins supple and stretchable, they are not stabilized and undergo more rapid deterioration. Chromium and potassium salts may not have been available for Paleoindians to use for tanning purposes. Iron oxide, or ocher, on the other hand, may have been more available in surface exposures or near surface deposits like the Powars II "mine" in southeastern Wyoming (Tankersley et al. 1995). Archaeologists should investigate the functional role of red ocher in skin and hide processing in much more detail. Philibert (1994) suggests that powdered ocher was used during the scraping of animal skins. Archaeologists should conduct a range of experiments to determine if red ocher enhances the use life of skin clothing, bedding, and tent covers. We also need to know if red-ocher treatments are used to make animal skins more water resistant, insect resistant, more supple under cold climatic conditions, or more stable if the skins are not depilated.[8, 9]

### Archaeological Correlates of Clothing Manufacture

Implements associated with the manufacture of skin clothing have not been given much attention by archaeologists (cf. Issenman 1997). We might expect to observe a range of implements in the archaeological record for late-glacial Paleoindians (Table 2-6). Eyed bone needles have been found in Solutrean, Magdalenian, and Gravetian sites (Borziyak 1993; Grigor'ev 1993; Hemingway 1980:203; Klein 1969, 1973; Stordeur-Yedid 1979; Tattersall 1995).[10] Archaeologists have recovered a number of eyed bone needles from Paleoindian sites in North America (e.g., Broken Mammoth, Alaska; Buhl Burial, Idaho; Lindenmeier, Colorado; Agate Basin, Wyoming; Winkler-1, New Mexico; Horn Shelter, Texas; Dust Cave, Alabama). At the Agate Basin site, it appears that Paleoindians made eyed bone needles from sections of bison scapulae (Frison and Craig 1982).

### *Shelter*

Winter houses make use of three major mechanisms to reduce heat loss. First, the house traps still, warm air between the floor and the ceiling and thus provides insulation. Second, the ceiling prevents the convection of heat from the house's interior to the external environment. Third, the floor covering or elevated sleeping areas reduce heat loss from the human body via con-

**Table 2-6.** *Artifactual Correlates of Animal-Skin Clothing Manufacture*

**Hide Removal and Preparation:**
Knives used for skinning
Chipped-stone, plano-concave scraper blades
Scraper handles
Bone scraper
Fleshers
Skin-cleaning tools, one piece— antler or ivory

**Cutting Out Clothing Skins:**
Chipped-stone knife
Cutting board

**Sewing:**
Bone needles, eyed or grooved
Needle sharpener, grooved sandstone or pumicelike stone
Fine-pointed bodkins or awls
Thimbles, ring or hood
Needle cases—stoppered bone tubes; open bone tubes with leather strap and "end buttons"
Sinew thread—back tendons of caribou
Sinew thread reels, double ended—bone, antler, or ivory
Sinew combs, single piece—two to four teeth
Sinew "guides" or "dies," bone with various-sized drilled holes
Fasteners for "housewives," or sewing kits—bone or ivory with designs or effigies

duction through the feet and/or the body's surface. In high-latitude settings, hunter-gatherers frequently constructed small single-family dwellings that required little heat. In a number of cases, such winter houses were warmed solely by human body heat.[11]

Some of the most significant information about Late Glacial period (20,000–18,000 $^{14}$C B.P.) dwellings comes from the Upper Dneper River drainage in the southwestern portion of the Mammoth Steppe in the Central Russian Plain (Soffer 1985). There, house features consisted of circular or oval concentrations of mammoth crania, mandibles, and tusks as well as an array of postcranial bones that ranged in floor area from 8 to 27.5 $m^2$ (Soffer 1985:Tables 6.16 and 6.18). Total mammoth-bone weight for the dwellings ranged from 4,815 to 15,721 kg. Many dwellings contained hearths, and the most prevalent fuel was "green," or fresh, bone. The clusters of dwellings were found in association with "mammoth cemeteries," or natural accumulations of mammoth bone within the floodplains of major rivers (Gromov 1948; Soffer 1985; Vereshchagin 1971, 1979).[12]

Those deposits would then represent naturally occurring stores of meat that could be scavenged. The green bone could then be used for shelters as well as

fuel. Unlike such Old World populations, Paleoindians may have remained quite mobile and may have retained large home ranges. It is unclear at present whether the environmental conditions existed for the deaths of large numbers of mammoths and subsequent freezing and burial in permafrost and ice. Consequently, archaeologists may not find similar mammoth-bone structures in the archaeological record for Paleoindians in the Americas.

Archaeologists know very little about the kinds of shelters that Paleoindians constructed. First, Binford (1990) has provided a number of generalizations regarding diet, mobility, portability of housing, and transport technology that we can apply to late-glacial hunter-gatherers.[13] Second, he (1990:133) proposes that hunter-gatherer dependence on terrestrial animals increases directly with latitude and inversely with effective temperature (ET °C). Consequently, hunter-gatherer mobility tends to increase in such high-latitude settings (Binford 1990:137).[14] Third, there is a strong correlation between hunting, mobility, portable housing, and use of a relatively elaborate transport technology (e.g., pack animals, travois, sleds, and watercraft).

One of the most important raw materials for constructing shelters is wood. Any expectations regarding Paleoindian housing, then, must take wood availability and quality during the Late Glacial period into account. Wells (1992) suggests that more than 50%–60% of the Great Plains region was essentially barren of vegetation during the LGM (20,000–18,000 $^{14}$C B.P.).[15] Recent reexaminations of pollen records from the Great Plains suggest that previous environmental reconstructions of spruce and pine forests in that region are erroneous (Adams 1997; Holliday 1987; Wells 1992). Recent vegetative maps produced by Adams (1997) and Adams and Faure (1997) suggest that the northern Great Plains including North Dakota changed from a dry steppe-desert (15,000–13,000 $^{14}$C B.P.) to a dry steppe (13,000–9000 $^{14}$C B.P.).

If trees were present, they may have been quite scarce, thinly scattered, and unsuitable for use as tent poles, roof poles, or support posts. Wood scarcity imposes significant restrictions upon housing design and construction—particularly for highly mobile, pedestrian hunter-gatherers during the winter.[16] We might, then, expect that Paleoindians throughout much of the Great Plains would have lived in skin tents that minimized the use of wood. Some central Arctic (Baffin Island) skin tents were elongated and made use of ridgepoles (Nabokov and Easton 1989:201, *middle right*). This tent form has a low profile, an expanded floor area, and shorter poles (Figure 2-5). Paleoindian families living in wood-scarce environments may have made use of an animal-skin tent similar to the Baffin Island Eskimo design.

The centerlines of the roofs or the tops of the tents were perhaps kept quite low to the ground in order to minimize the adverse effects of strong winter winds. Also, lower tent profiles would reduce the volume of the tent's interior and its attendant heating costs (Tables 2-7 and 2-8). Wood fuel for purposes of heating and cooking during the winter may also have been scarce. Interior hearths were probably very small or nonexistent. Such hearths in the northern Great Plains may have been fueled with grass or green bone. The animal skins used for tent covers were probably made from intermediate-sized mammals (e.g., caribou, camelid, deer, elk, or antelope).

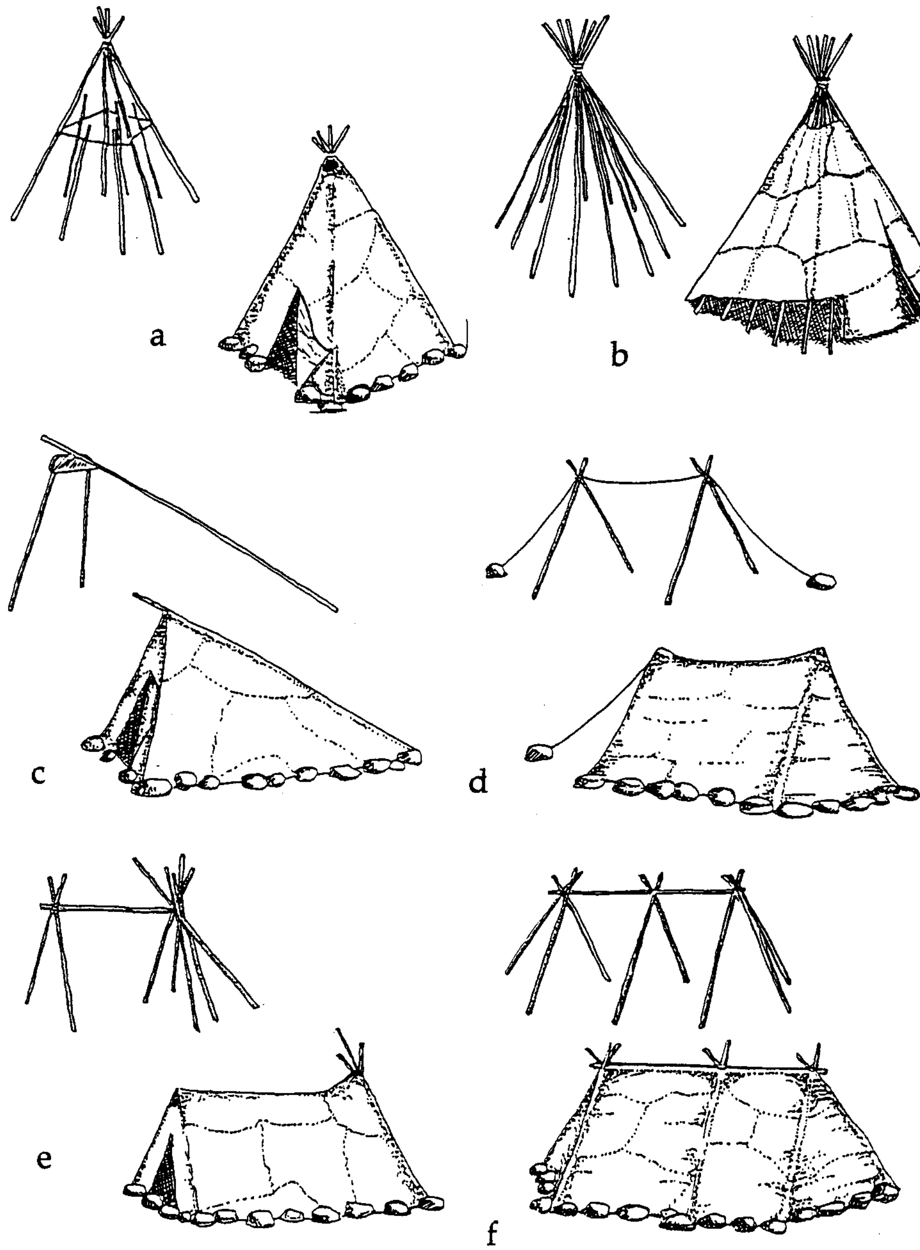


**Figure 2-5.** *Variation in the construction of high-latitude skin tents:* (a) *west Alaskan coast conical tent;* (b) *Yukagir conical tent;* (c) *Angmagssalik Eskimo ridge tent, Greenland;* (d) *Iglulik Eskimo ridge tent;* (e) *idealized North American Paleoindian tent, minimal wood* (a–d, *adopted from Faegre 1979).*

**Table 2-7.** *Comparison of Physical Characteristics of A-frame and Conical Skin Tents*

| *Shape* | *Max. Height (m)* | *Surface Area ($m^2$)* | *Number Bison Hides* | *Total Wt. Hides (kg)* | *Floor Area ($m^2$)* | *No./Wt. Poles (No./kg)* | *Total Tent Wt. (kg)* | *Vol. ($m^3$)* |
|---|---|---|---|---|---|---|---|---|
| A-frame | 2 | 26.6 | 6.27 | 30.11 | 12 | 7/21.24 | 51.95 | 13.5 |
| Conical | 2 | 29.02 | 6.83 | 32.77 | 12 | 7/21.24 | 54.2 | 8 |
| A-frame | 2 | 39.1 | 9.2 | 44.16 | 19.5 | 10/31.2 | 78.2 | 21 |
| Conical | 2 | 44.8 | 10.54 | 50.6 | 19.5 | 10/36.4[a] | 87 | 13 |

[a]Poles are 3.5 m long.

The A-frame tent design offers more than twice the total volume of air than does the conical tent. This characteristic would be disadvantageous for groups who used the design for a winter shelter that was to be heated either with fuel or body heat. The A-frame design can be enlarged to offer greater floor area without requiring longer tent poles, and it can be enlarged by lengthening the structure. The conical tent's floor area cannot be enlarged unless longer poles are used (Table 2-8). Due to the increased weight of tent poles, larger conical tents with variable heights (2, 3, and 4.8 m) exhibit increasingly higher transport weights (costs). For example, both the A-frame and the conical tents with equivalent floor areas of 19.5 $m^2$ have total transport weights equal to 78.2 kg and 189.45 kg, respectively. Domesticated dogs may have been used to transport much of the weight (Ewers 1955; Lowie 1954).

### *Fire and Fuel Sources*

Fire and fuel use has not been given much attention by archaeologists—especially related to hunter-gatherers. Information regarding the Paleoindian use of fire is scant. Select information regarding hearths and fuels used by late-glacial hunter-gatherers in Eastern Europe, Siberia, and the Americas is presented in Table 2-9. Kelly and Todd (1988) and Todd (1991) discuss the paucity of archaeological evidence related to Paleoindian use of fire, particularly for bone-grease processing and for cooking.

Guthrie (1990a:277) argues that the Mammoth Steppe would have been "a hostile environment for early people," and it would have provided little, if any, wood for "shelter, fuel, or tools." Guthrie (1990a) overlooks a number of fuel sources that may have been available to Paleoindians, including animal fats and oils, scrubby vegetation, moss, lichens, grass, heather, peat, driftwood, and animal dung (see Wright 1992). Weyer (1969:102–103) states, however, that the terrestrial-mammal fat is scarce in winter and is a "miserable substitute" for marine-mammal oil and blubber. Some Eskimo groups were

**Table 2-8.** *Conical Skin-Tent Characteristics Given Constant Floor Area and Varied Height*

| *Shape* | *Max. Ht. (m)* | *Surface Area ($m^2$)* | *No. Bison Hides* | *Total Wt. Hides (kg)* | *Floor Area ($m^2$)* | *No. Poles* | *Length Poles (m)* | *Wt. Poles (kg)* | *Total Tent Wt. (kg)* | *Vol. ($m^3$)* |
|---|---|---|---|---|---|---|---|---|---|---|
| Conical (low) | 2 | 44.8 | 10.5 | 50.6 | 19.5 | 10 | 3.5 | 36.4 | 87 | 13 |
| Conical (medium) | 3 | 49.5 | 12 | 56 | 19.5 | 10 | 4.3 | 45 | 101 | 19.6 |
| Conical (tall[a]) | 4.8 | 62.83 | 15 | 71 | 19.5 | 18.34 | 6.21 | 118.45 | 189.45 | 31.4 |

[a]Calculations based on "average" Plains tipi measurements and hide:pole requirements for a lodge with floor area equal to 19.5 $m^2$.

well known for their very efficient use of wood for cooking meat during the winter and on long treks some distance from tree cover.[17–20] A very cursory compilation of archaeological data (Table 2-9) regarding Late Glacial period hearths and their contents suggests a shift in fuel use from animal bone to wood (Figure 2-6).

## Implications for the Study of Paleoindians

The preceding discussion was meant to explore several possible technological responses that late-glacial hunter-gatherers may have made to cold stress in North America. While we are seeing a tremendous resurgence in Paleoindian archaeology, many investigators have not studied cold stress or other ecological constraints of the periglacial world. In many cases, archaeologists and paleoanthropologists pay even less attention to the biology and the behavior of the Late Glacial period hunter-gatherers to whom we refer as "Paleoindians" or "Paleoamericans" (Bonnichsen and Turnmire 1999:1). A number of basic assumptions and interpretations that continue to guide Paleoindian investigations have not been examined critically. Archaeologists can be more cognizant of those assumptions if they make better use of paleoenvironmental models, environmental physiology, human nutrition, and cross-cultural studies linked to relevant biophysical variables.

Several implications of the previous discussion are as follows:

1. Warm, dry clothing would have been extremely important for survival during the very cold winter season. Clothing and shelter would have been so important that the demand for large-mammal skins (as well as

**Table 2-9.** *Late Glacial Period Use of Hearths and Fuels*

| *Site* | *Location* | *Date B.P.* | *Hearth Type* | *Fuel* | *Reference* |
|---|---|---|---|---|---|
| Kostenki I-1 | Russian Plain | 24,100–21,300 | 11 hearths; < 1.10 m dia., 0.20 m deep | Animal bone (bone ash and charred bones) | Klein (1969) |
| Avdeevo | Russian Plain | 22,700–17,200 | Hearths | Animal bone (burned bones) | Svezhentsev (1993) |
| Iudinovo | Siberia | 15,000–13,000 | — | Animal bone | Abramova (1993) |
| Kokorevo I | Siberia | 14,450–12,940 | Circular pit; rock slab lined | Wood—willow, larch, spruce | Abramova (1993) |
| Mezhirich | Russian Plain | 19,280–14,300 | Circular; inside and outside houses | Mammoth bone | Soffer (1985) |
| Pushkari | Russian Plain | 16,775 | — | Mammoth bone | Soffer (1985) |
| Tel'manskaya Horizon 1 | Russian Plain | — | Circular pit, 0.75–0.80 m dia., 0.15–0.20 m deep | Mammoth bone | Klein (1969:141–142) |
| Buiunda-3 | Upper Kolyma region, Western Beringia | 8130–5610 | Hearth | Charcoal, wood | Goebel and Slobodin (1999:113) |
| Kongo | Upper Kolyma region, Western Beringia | 8655–8080 | Hearth | Charcoal, wood | Goebel and Slobodin (1999:113) |
| Ushki Sites | Kamchatka Peninsula | Cultural Level VII 14,200–14,300 | Multiple hearths within house features | Charcoal, wood | Dikov (1996) |
| Mesa | Northern Brooks Range, Alaska | 11,660–9900 | 15 hearths, shallow lenticular; 17 cm dia., < 12 cm thick | Charcoal, wood | Kunz and Reanier (1995) |
| Broken Mammoth | Alaska | 10,300 11,800–11,000 | Hearth; hearth smears | Charcoal, wood (?) | Yesner et al. (1992); Holmes (1996) |
| Walker Road | Alaska | 11,330 | Two hearths | Charcoal, wood | Goebel et al. (1991) in Hamilton and Goebel (1999:162) |
| Hidden Falls | Alaska | 9060 | Elliptical scatters of fire-cracked rock | Charcoal, wood | Davis (1996:421) |

**Table 2-9.**—*Continued*

| *Site* | *Location* | *Date B.P.* | *Hearth Type* | *Fuel* | *Reference* |
|---|---|---|---|---|---|
| Healy Lake | Alaska | 11,090 | Oval, pit hearth (28 x 45 cm) | Burned bone | Cook (1996) |
| Moose Creek | Alaska | 11,190 Nenana Complex | Hearth | Charcoal, wood (?) | Pearson (1997) |
| Debert | Nova Scotia | 10,604 | Hearths; relatively shallow, irregular pits | Charcoal, wood | MacDonald (1968) |
| Tule Lake | California | 11,450 | Small fire pit; 18 cm dia., 5 cm deep | Wood, burned | Beaton (1991) |
| Barton Gulch | Montana | 9410–9080 | Earth ovens/ roasting pits | Charcoal, wood (?) | Eighmy and Davis (1997) |
| Agate Basin | Wyoming | Folsom | 30 cm dia., 76 cm dia. | Calcined bone | Frison (1982) |
| Hanson | Wyoming | Folsom | Shallow 5 cm | Calcined bone and oxidized soil | Frison (1991) |
| Caribou Lake | Colorado | 8460 | Steep-sided basin, 25 x 32 cm | Charcoal, wood | Benedict (1992) |
| 5BL70 | Colorado | 7650 | Shallow, circular, 50 cm dia. | Charcoal, wood | Benedict (1992) |
| Allen | Nebraska | 11,000–8000 | Unprepared surface hearths | Charcoal, wood | Wedel (1986:70); Bamforth (1991:360–361) |
| 25BF14 | Nebraska | Late Paleoindian-Scottsbluff | Prepared pits; filled with burned bison bone and white ash | Bison bone; dung (?) | Steve Holen (personal communication 1999) |
| Waugh | Oklahoma | 10,390 Folsom | Unprepared surface hearth; 60 x 100 cm; 5 cm thick | Charcoal, wood; calcined bone (bison sacrum) | Hofman (1994) |
| Horrace Rivers | Texas | 9300–9000 Plainview | Hearths | Charcoal, wood | Mallouf (1992) |
| Midland Locality 1 | Texas | < 10,000 | 2 hearths: 1 m dia.; burned caliche rocks, 2.5–7.5 dia. | None observed | Wendorf et al. (1955) |
| Lewisville | Texas | Clovis | Hearths | Lignite | Stanford (1983:70) |
| Aubrey | Texas | Clovis | Hearths | Burned bone | Ferring (1995:278) |
| Shawnee Minisink | Delaware | 10,590 | Hearth | Charcoal, wood | McNett (1985) |

**Table 2-9.**—*Continued*

| *Site* | *Location* | *Date B.P.* | *Hearth Type* | *Fuel* | *Reference* |
|---|---|---|---|---|---|
| Meadowcroft Rockshelter | Pennsylvania | 16,175–12,800 | Fire pits | Charcoal, wood | Adovasio (1988) |
| Cactus Hill | SE Virginia | 16,670 Clovis | Possible hearth | Carbon | McAvoy and McAvoy (1997) |
| | | 10,920 ± 240 | Hearth | Hard Southern-pine charcoal | |
| Page/Ladson | Florida | 10,200 | Hearth; 28 cm x 41 cm; 10 cm deep | Charcoal, wood | Muniz (1997) |

small-mammal skins for ruffs and, in some cases, bird skins and feathers for undergarments) may have equaled or exceeded the demand for food. Such nonsubsistence needs would have had to be anticipated far in advance. Failure to acquire, process, and fashion animal hides and related products into clothing and shelter would have been catastrophic. Like food-getting strategies, the procurement of animal hides had to have been closely tied to the availability, abundance, and condition of the target animals.

Furthermore, winter clothing requires a fairly diverse array of animal skins and products. As discussed previously, the insulative properties (clo value) of mammal skins vary with fur thickness. Many of the best animal skins are obtained from carnivores—animals that are, in many cases, not used for food. The faunal remains of fur-bearing mammals recovered from Paleoindian sites may take on added significance in light of our concern with winter clothing. For example, Klein (1969:143, 171) describes a number of wolf and hare paws, as well as large quantities of red ocher, that were found in Upper Paleolithic Kostenki IV (Horizons 1 and 2) pit features along the Don River. He (1969:171) suggests that "these pits were used for the coloring and tanning of hare skins."[21]

2. Late Glacial period hunter-gatherers would have occupied "wood-scarce" environments. Although trees may have been present in certain areas in the northern Great Plains, we need to consider how suitable they would have been for the manufacturing of spear or dart shafts, certain tool hafts, sleds, and tent frames. For example, subalpine fir, Engelmann spruce, and limber and bristlecone pine trees in the Rocky Mountains today near the timberline are twisted, gnarled, and dwarfed in their cold, dry, and windy settings. Subalpine fir in such Arctic-like settings grows to heights of one to two feet (Elmore 1976). Wood generally serves as a very important "connective tissue" in hunter-gatherer technology (Osborn 1999). Consequently, archaeologists can expect to observe increased technological complexity (greater number of implements and greater number of component parts) in wood-scarce environments (Osborn 1999). The component parts of hunting weapons will also exhibit greater raw-material diversity (e.g., chipped stone, bone, antler, ivory, animal hide, and so forth).

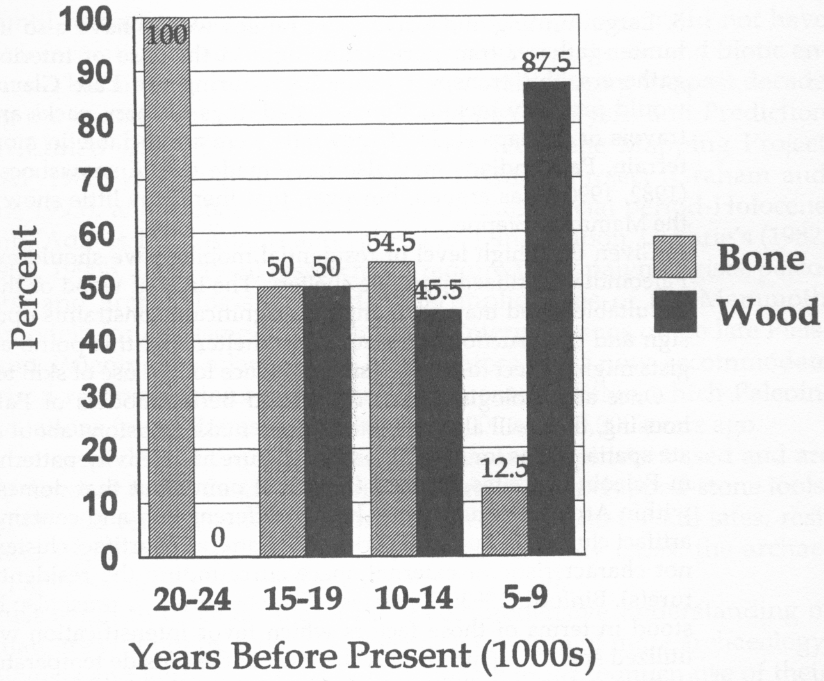


**Figure 2-6.** *Variation in hearth fuels for late-glacial hunter-gatherers.*

3. Also, we might expect, then, that Paleoindians would have made use of alternative fuel sources, including heather, grasses, animal bone and grease, and perhaps animal dung. We might also expect to observe seasonal or situational shifts in fuel sources throughout an annual cycle and/or seasonal pattern of land use. Animal fats and green bone may have been used during the winter months, whereas grasses, twigs, and/or animal dung may have been used during the summer months. It is also possible that late-glacial hunter-gatherers did not use hearths to cook their food or to heat their winter residences. Certain fuels (e.g., heather or grasses) or patterns of fuel use (e.g., use of wood chips or shavings) may not have left highly visible hearth features comprised of fire-reddened earth and dense concentrations of wood charcoal and ash.

4. We would anticipate that Late Glacial period hunter-gatherers would have inhabited environments ca. 12,100 $^{14}C$ B.P. that were characterized by ET values equal to 11°C or below. Based on predictions offered by Binford (1980) and Kelly (1995:Table 3.1), the estimated dependence on hunting equals roughly 80% (the best case to refer to here is the Blackfoot who made no use of aquatic resources). They would have been very dependent on hunting and scavenging of animals, and they would have been quite mobile. Given the high dependence upon hunting, we might expect to observe very large hunting territories (ca. 9,500 $km^2$). Plants would have contributed very little to Paleoindian diets throughout much of North America.

5. Large hunting and scavenging ranges would have also influenced hunter-gatherer transport technology. In the case of interior hunter-gatherers, this transport technology during the Late Glacial period would probably include domesticated dogs to carry packs and to pull travois or perhaps sleds. If snowfalls were appreciable in more broken terrain, Paleoindians may also have made use of snowshoes. Guthrie (1982, 1990a) has argued, however, that there was little snow cover on the Mammoth Steppe.

6. Given their high level of residential mobility, we should expect that Paleoindians utilized portable shelters. The lack of wood or the scarcity of suitable wood may have imposed significant constraints upon the design and construction of Paleoindian shelters. At this point, archaeologists might expect to find physical evidence for the use of skin tents.

Once archaeologists have developed better models of Paleoindian housing, they will also be better able to make decisions about appropriate spatial scales for studying site structure and activity patterning within Paleoindian sites. Binford (1983:183) points out that domestic space within Arctic structures were highly differentiated and contained dense artifact clusters including debris. Such patterns of artifact clustering were not characteristic of external space surrounding the residential structure(s). Binford (1983:186) states, "Site structure . . . must also be understood in terms of those factors which favor intensification within the utilized space . . . [such as] . . . the level of the outside temperature [that] is a major factor contributing to site structure, for the colder it becomes, the more activities must be conducted in sheltered spaces." On the other hand, "the construction of a structure or the use of a sheltered location tends to restrict the quantity and the distribution of light within it" (Binford 1983:186). He further states (1983:186) that "the more critical shelter becomes (mainly as a function of environmental constraints), the more differentiation of space use in response to lighting limitations may be anticipated." Such ethnoarchaeological insights may prove to be very valuable in our interpretations of Paleoindian site structure in cases such as Agate Basin, Wyoming (Frison and Stanford 1982), Hidden Creek, Connecticut (Jones 1997), Bull Brook, Massachusetts (Grimes 1979), Debert, Nova Scotia (MacDonald 1968), and Parkhill, Ontario (Spiess et al. 1998).

## Summary and Conclusions

Archaeological research focused upon Paleoindians, or Paleoamericans, has greatly intensified during the past decade (e.g., Anderson and Sassaman 1996; Bonnichsen and Turnmire 1991, 1999; Dillehay and Meltzer 1991; Holliday1997; Johnson 1995; Soffer and Praslov 1993; Stanford and Day 1992; West 1996). Although our knowledge about Paleoindians has grown significantly, investigators still lack any really robust understanding of the range of environmental constraints or problems that Paleoindians faced or how they solved them. There are several reasons perhaps why little progress has been made with respect to hunter-gatherer adaptations during the Late Glacial period for the Americas.

First, until recently, archaeologists and paleoanthropologists did not have sufficient information or adequate models of late-glacial abiotic and biotic environments. That situation changed quite dramatically during the past decade following the completion of the Climate: Mapping, Analysis, and Prediction Project (CLIMAP 1976, 1981), the Cooperative Holocene Mapping Project (COHMAP 1988; Wright et al. 1993), the FAUNMAP Project (Graham and Lundelius 1995), and global reconstructions of Late Glacial period-Holocene vegetation (Adams 1997; Adams and Faure 1997). In addition, Guthrie's (1982, 1988, 1990a, 1990b, 1995, 1996) research has required that palynologists, paleoecologists, and archaeologists consider the implications of the Mammoth Steppe "model" for assessing more traditional interpretations of the late Pleistocene and Paleoindian adaptations. Investigators must now accommodate such revised reconstructions of the ecological context within which Paleoindian populations found themselves between 20,000 and 10,000 years ago.

Second, a great deal of the Paleoindian studies are empiricist based and are primarily devoted to the description and interpretation of chipped-stone tools, debitage, animal remains, and geomorphological contexts for kill sites, residential and logistical locations, and tool caches. In many cases, the archaeology of Paleoindians is examined at a site-specific level.

We must begin to consider that a more comprehensive understanding of Paleoindian life will not be achieved solely as a function of more archaeology. Archaeologists and anthropologists will be unable to make much use of their own personal experiences in order to anticipate or to interpret the nature of the archaeological record. It will be extremely difficult, if not impossible, for researchers to "imagine" what the late-glacial world was like. Our understanding of Paleoindian life will most probably be achieved via the construction of a complex web of robust generalizations, reliable knowledge, and computer simulations involving glaciology, paleoclimatology and paleoecology, human morphology, physiology, nutrition, human-reproductive ecology, socioecology, and archaeology. We may then be able to anticipate the array of biological and behavioral responses that such Late Glacial period and early Holocene populations made to abrupt climate change, loss of biodiversity, major shifts in ecological patch structure, low human population densities, high residential mobility, cold stress, extreme aridity, wood scarcity, and physiographic changes. Further research regarding human cold-stress and associated adaptive responses may bring archaeologists somewhat closer to such a goal.

## Notes

1. Guthrie and Stoker (1990) point out that Pleistocene horses dominated the triad of grazers (mammoth, bison, and horse) on the cold, extremely arid North Slope of Alaska. Their intensive analysis of the hooves of the Titaluk horse indicates that horses were less mobile during the dry winters and that they spent much of their time grazing upon a dry, smooth, nonabrasive substrate or soil.

2. The insulation value is measured in clo units (1 clo unit equals a reduction of heat loss from the skin equal to 38 kcal/$m^2$/hr; Folk 1974:146).

3. "Skin and sub-clothing temperatures fall when fully clothed men go outside in the Antarctic. Skin temperature has been shown to be related to the exposure climate but relatively unaffected by activity. Skin temperatures of the order of 27°C (range from 30°–20°C) have been observed for men working outdoors. . . . Thus a man sitting in his tent requires a skin temperature of about 32°C for comfort, but can tolerate skin temperatures of 27°C when sledging. . . . Indeed a low skin temperature is an advantage, as it allows strenuous work to be performed without excessive sweating. It seems probable that low skin temperatures also enable men to sustain work rates that would be curtailed by overheating in warmer environments" (Brotherhood 1974:190).

4. Åstrand and Rodahl (1970) point out that the amount of respiratory water loss for humans is a function of ventilation and humidity. We would expect that highly active, mobile hunter-gatherers during Late Glacial period winters would have lost considerable water while wearing well-ventilated clothing in a fairly dry, cold climate. Freshwater requirements would have been considerable during that season.

5. Gramly (1977:602) estimates that 18,000 historic Huron of Ontario would have consumed at least 64,000 deer hides in a year (or an average of 3.5 deer hides per person per year). Gramly (1977:602) also points out that one must include hides that were to be used for footgear (e.g., moccasins). He (1977:602–603) states, "According to Turner (1894:285) the Naskapi could produce five to seven pairs of moccasins from a single hide [white-tailed deer]." Saladin d'Anglure (1984:491) remarks that an "affluent" Tarramiut (Inuit of Quebec) family consisting of three adults and two children required 40 caribou skins for their annual clothing needs. Winter clothing (one outfit including an inner parka, an outer parka, mittens, stockings, boots, and pants) for one individual required 12 caribou hides. Banfield (1954) states that the winter outfit might have lasted two years, but it was usually replaced each year. An extended family consisting of seven people would then have had to procure, process, and fashion 84 caribou hides into needed winter clothes each year. This estimate does not include the number of caribou hides that would have been needed for tents, bedding, and other domestic purposes.

6. Haired skins (hides with fur) underwent the following treatment: (1) hides were cleaned of fat, meat, and blood stains; (2) hides were staked fur side down to the ground to dry; (3) hides were scraped for about two hours with caribou-scapula, chipped-stone, or iron blades, using short (10 cm, or 4 in) strokes from the edges toward the center; (4) scraped surface of the hide was wetted with one-half liter of water, rolled up, stored for 24 hours, unrolled, and stretched with a dull-edged stone; (5) moist hide was then stretched and scraped for the second time until it became velvety-soft and supple; sometimes the hides were chewed, rubbed, twisted, and stretched; (6) the hide might then have been wrung dry or frozen for about a week; (7) a final scraping might have been continued "for several hours until the high pitched scratchy sound of the scraper against the skin [became] low and resonant" (Oakes 1991:111).

7. Red ocher has also been used by Paleoindians as a polishing agent in the context of chipped-stone tool manufacture. Titmus and Woods (1991) discuss the use of powdered ocher for polishing the lateral margins of chipped-stone tools. They (1991:198) state, "The above polishing experiments indicate there could be functional as well as ritual explanations for the recovery of red ocher found at some sites [Paleoindian]." They (1991) argue that edge grinding and polishing reduce the likelihood of point fracture or bending stress on weapons.

Reher and Frison (1991:390) describe pronounced grinding on flake-scar ridges exhibited on Paleoindian projectile points made from quartz crystal. They (1991:390)

state, "Transport damage has also been suggested as a cause of these localized areas of abrasion on Clovis cache bifaces and points, that is, some form of transport where the medium used for storage gradually rubbed on the interflake ridges. The common association of the caches with red ocher, an excellent polishing medium, is one possible factor."

8. Red ocher has been used for two additional purposes. First, Frison (1991:367) suggests that red ocher "does serve to protect and prolong the life of wooden materials." Spencer and Gillen (1968:568) argue that central Australian hunter-gatherers applied red ocher and grease to wooden churingas and implements in order to protect them from termites or white ants.

9. Ocher was also used for "sun screen" or protective treatment for the skin. The Tehuelche of Patagonia smeared their bodies with grease and/or white earth or white, black, red, or yellow pigments. Cooper (1946b:146) notes, "[f]ace painting with black on the march or on cold days to protect skin (Viedma 1837:81)." Jacobsohn (1995:175–176) states that among the Himba of Namibia the "[w]omen said when it [animal fat] was mixed with och[er] and herbs, it also helped to keep them cool by acting as a barrier from the sun." Bannister and Johnson (1990) elaborate further on the use of body "paints" by Himba women who coat their entire bodies with a mixture of red ocher, butter, aromatic herbs, and Kaokoveld myrrh.

10. Borziyak (1993:75) states, "Eyed needles, for example, are found in almost all of the layers at Ksoutsy. They were made from vertical segments of long bones, split by flint burins, and sharpened and polished by stone abraders. Their narrow openings, made by flint bladelets, indicate that fine thread was used to stitch the hides."

11. For example, Weyer (1969:103) states, "All members of the Caribou group apart from the Hauneqtôrmiut and a very few Qaernermiut pass even the coldest winters without any artificial heat [other than body heat] whatever."

12. Such bone beds occur relatively frequently in Siberia. Lister and Bahn (1994:145) provide a description of the Berelekh site in northeastern Siberia where a mammoth bone bed stretched 180 m (590 ft) along the bank of the Berelekh River. That bone-bed deposit was immense, and "it is estimated that over the past 100 years up to 50,000 bones from 200 mammoth could have been naturally washed out and redeposited in the riverbed" (Lister and Bahn 1994:145). The paleontological site appears to represent a long-term accumulation of mammoth remains within a stream meander while the mammoth carcasses were fresh. The animals may have been trapped along the stream channel, and/or they may have drowned.

13. It should be pointed out that Binford's generalizations are frequently phrased with respect to modern or late Holocene environmental gradients (e.g., tropical, subtropical, temperate, northern temperate, and arctic). We can make use of his generalizations (correlations), however, if we make use of the associated effective temperature (ET °C) values.

14. Binford (1990:134) continues, "The returns per unit increase in mobility, nevertheless, continue to go down as one moves toward the poles, thus providing a very strong selective context favoring any alternative food-getting strategy that will reduce the search time and simultaneously increase the return rate per unit of search time." Binford (1990:134) states that under such conditions modern hunter-gatherers shift toward increased dependence upon anadromous fish, other marine fish, and sea mammals. Aquatic-resource exploitation in the circumpolar region was not an option during most of the Late Glacial period (18,000–8000 B.P.).

15. Adams (1997:6) states, "In the High Plains, the drier western part of the present North American steppe region which presently has mainly short-grass prairie vegeta-

tion, LGM [Late Glacial Maximum] conditions seem to have been very arid." Wells (1992:316) describes geomorphological evidence for major aeolian deposition during the LGM for an area that stretches from southern Saskatchewan to northwest Texas. Adams (1997:6) states, "On the basis of the morphology and extent of the dunes of the Nebraska Sand Hills dating to the last glacial, between 22,000 and 12,500 years ago, Wells (1992:317) suggests an annual precipitation at the LGM of less than 50 mm . . . in contrast to the present 600 mm." As Adams (1997:6) recounts, "A more likely explanation is that the conifer pollen is derived from long-distance transport and that selective preservation against decay (conifer pollen is generally more robust than angiosperm pollen) has disguised a mainly herbaceous plant community existing at that time."

16. One of the most likely candidates for a Paleoindian habitation structure was found within Area 2 of the Folsom component at the Agate Basin site in Wyoming. Archaeological evidence for the structure consists of a small hearth (30 cm dia.; 8 cm deep) surrounded by a roughly circular concentration (ca. 3.7 m dia.) of chipped-stone tools and flaking debris, 6 bone needles, 2 bone points, 1 worked bone, and 2 concentrations of small flakes (5,450; Frison and Stanford 1982:Figures 2.16 and 2.17). Several stones or manuports, as well as one upright bison rib "tent stake," were found around the margins of the artifact concentration. The total floor space encompassed by the possible structure equals 10.2 $m^2$. The spatial arrangement of the hearth and associated artifact assemblage in Area 2 of the Folsom occupation at Agate Basin coincide quite well with our expectations for a Paleoindian tent structure.

17. Todd (1991:229) states, "Instead, hearths are usually very shallow unprepared features, such as those reported by Frison from the Folsom . . . and Hell Gap . . . levels at the Agate Basin site . . . , or they are represented by very sparse scatters of charcoal. Evidence of burning in Paleoindian contexts therefore points to very short term surface fires."

18. Stefánsson (1914:45) states, "The man of the family would take an adze and with it make fine chips or shavings which the woman would feed one by one into a tiny flame built under the bottom of the pot. In this way a very small piece of wood could bring a good-sized pot of meat to a boil."

19. Mary-Rousselíere (1984:434) describes the use of animal bone "doused in [sea mammal] oil" as fuel for summer cooking fires by the Iglulingmiut Eskimo. He (1984:434) also states that "fires were started by striking pyrite with flint or by a wooden fire drill driven by a cord or bow." Coastal groups of Inuit of Quebec made use of beluga oil for cooking, lighting, and heating large winter igloos, or in summer they burned driftwood or animal fat mixed with "old" animal bones (Saladin d'Anglure 1984:491). Interior groups "even had to do without heating, using caribou tallow for lighting and cooking over a twig fire" (Saladin d'Anglure 1984:482).

20. Fire-making kits used by Paleoindians might have contained bow drills (also used for tool making and repair), iron pyrite and "flints" (strike-a-lights), a wooden "hearth" (see Jenness 1970:Figure 46), a small bag, grass/tender, "moss root," and small lamps (curated or expedient pebble/cobble or "saucer-shaped" or stone slab with depression).

21. Klein (1969:143) states, "Of particular interest is the relatively large number of skeletal parts (phalanges, metacarpals, and metatarsals) of wolf paws, frequently found in at least partial anatomical order. Since paws are often removed with the pelt during skinning, the evidence at Tel'manskaya may indicate considerable use of wolf pelts."

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