THULE-ERA FUEL SELECTION AND MANAGEMENT AT CAPE ESPENBERG, ALASKA

Laura J. Crawford
The Ohio State University, Department of Anthropology, 4082 Smith Laboratory, 174 W. 18th Ave., Columbus, OH 43214;
crawford.819@buckeyemail.osu.edu

ABSTRACT

In the Arctic, fuel is as crucial to survival as food and fresh water. Until recently, however, Arctic archaeologists have largely neglected to study fuel use. To address this knowledge gap, I examined fuel use at two Thule-era houses dated from about AD 1500 to 1800 at the Rising Whale site, Cape Espenberg, Alaska. Results suggest that inhabitants selected firewood according to condition- and taxon-specific properties and burned wood in combination with bone and sea mammal oil. The quantities of different woody taxa and fuel types illustrate how Thule managed these resources. Differences between houses and contexts suggest Thule people manipulated the combustion properties of fire to suit their needs. Oral history suggests that driftwood availability eventually declined at the site. The use of timber construction and ample wood charcoal, however, suggests this decline occurred after Thule times. This decline may have been exacerbated by the introduction of fuel-hungry woodstoves. The combination of woodstoves and a decline in driftwood deposition may have helped to motivate the Iñupiat to abandon the area in the late nineteenth and early twentieth century.

INTRODUCTION

Even in the treeless Arctic, wood is a critical resource, and on western Arctic coasts driftwood was the main source of wood. The postcontact Iñupiat needed large quantities of wood for construction, boat building, manufacturing tools, and fuel in steam baths, smoking fish, and sometimes cooking (Alix 2016). Constructing a wood-framed sod house required upward of 20 trees, and large communal *qargis* (men's houses) needed about twice that amount (Mason 1998:290). The presence of similar structures at archaeological sites suggest that this trend extended well into the past.

Giddings (1952a) suggested that Alaskans have long reserved driftwood for purposes other than fuel (see also Saario and Kessel 1966). As such, Arctic people sought to conserve woody fuel in several ways. For instance, the postcontact Iñupiat boiled food in ceramic or soapstone vessels (Harry and Frink 2009), used sea mammal oil as their primary fuel, and extended the life of their fires by adding bone fuel. Ceramic production, however, was fuel-intensive because vessels were fragile and short-lived (Frink and Harry 2008).

Group needs determined whether an area had sufficient wood. Wood availability was important when choosing settlement sites (Burch 2006:52), and it likely limited population size in some areas (Giddings 1941; Mason 1998). Even where driftwood was abundant, acquiring adequate fuel required considerable time and energy.

Coastal Alaskans depended upon the annual delivery of driftwood. Driftwood availability, however, differed from region to region (Giddings 1952b) and year to year (Alix 2005). Climate and topography are major factors determining driftwood deposition. Most Alaska driftwood originates from the forested interior, where precipitation, spring temperatures, and flooding recruit trees into rivers. The height of floods, the number and intensity of storms, and storm trajectory determine the quantity of driftwood delivered. Such idiosyncrasies complicate attempts to reconstruct past driftwood availability (Alix 2005; Mason 1998; Mason and Begét 1991).

Paleoclimatic reconstructions for the last 400 years suggest interior Alaska rivers experienced heightened flooding (Mason and Begét 1991). Moreover, there was increased storminess in the Bering Strait and Chukchi Sea (Mason and Jordan 1993). This combination would have shipped more logs to sea and increased coastal delivery. Thus, driftwood deposition would have likely increased during the last 400 years of occupation at Cape Espenberg. Additionally, in the nineteenth century, ethnohistorical reports speak of abundant driftwood delivery (Alix 2012:90).

Regional and local driftwood availability shifts over time. Today, there are sites with little driftwood compared to what is found in archaeological contexts. Archaeological sites in Alaska and Canada like Cape Espenberg, Cape Lisburne, and Skraeling Island seemingly had more driftwood during the last millennium than at present (Alix 2001, 2009a; Crawford 2012; McCullough 1989). Current driftwood concentrations appear insufficient to support the wood usage seen at these sites. If driftwood availability declined, inhabitants would have traveled longer distances for wood, spent more time finding preferred wood, settled for less desirable wood, and used alternative materials and fuel sources (Alix 2005).

This research seeks to understand fuel management strategies and responses to changing driftwood availability at the Rising Whale site, Cape Espenberg. This study examined two late Western Thule houses, Feature 68A and Feature 33, dated between about AD 1500 and AD 1800. To manage their fuel supplies, Cape Espenberg's residents made calculated cost-benefit decisions about what fuels to burn and in what quantities. They burned all available driftwood taxa, shrubby vegetation, bone, and sea mammal oil in various combinations. There is, however, a curious lack of *Populus* spp. charcoal (aspen/cottonwood/poplar genus), which is one of the most common driftwood taxa in northwestern Alaska today (Alix 2005). Poplar's absence raises questions about how Thule people categorized and selected firewood according to variables like diameter, combustion properties, humidity, smokiness, and others.

Cape Espenberg was occupied well into postcontact times. Its last residents, the Pittagmiut, abandoned the area in the late nineteenth and early twentieth centuries for unclear reasons (Burch 1998:303). Shifting tribal boundaries (Schaaf 1996) and declining caribou (*Rangifer tarandus*) numbers (Burch 1998) may have led to abandonment. Clifford Weyiouanna, a Shishmaref resident, suggested that insufficient wood also contributed to Cape Espenberg's abandonment. While some have argued that driftwood deposition led to depopulation during Thule times, evidence from this study suggests that driftwood shortages did not occur until centuries later.

CONTEXT OF THE RISING WHALE SITE

Cape Espenberg is a 29 km long sandy spit on Alaska's northwest coast. This peninsula rises just above the Arctic Circle, making it the Seward Peninsula's northernmost extension (Mason et al. 1997). It is surrounded on three sides by Kotzebue Sound and the Chukchi Sea. The spit's topography consists of late Holocene storm-deposited beach berms, capped by low dunes separated by marshy swales and thaw ponds (Mason 1990; Mason and Gerlach 1995; Mason et al. 1997). Over the past 5000 years, the spit has prograded seaward more than 2 km, adding over 20 beach ridges parallel to the shore. These dunes vary in height from less than 1 m above sea level to over 10 m. Apart from ridge E-14—the "Norton ridge"—the highest dune ridges are typically those closest to the modern shoreline (Mason 1990; Mason et al. 1997). Fig. 1 shows Cape Espenberg's location in Alaska, the location of Features 33 and 68A, and the topography of the spit.

Cape Espenberg's climate is like that of the larger Kotzebue Sound region with cool, maritime summers and extremely cold winters. Toward the end of the twentieth century, Cape Espenberg's coast was ice-fast from at least November to early June (Leslie 1986). The mean annual temperature was –5°C, and July's mean temperature was about 15°C from 1981 to 2010 (Arguez et al. 2010). These values are not typical of weather conditions during Thule times and do not reflect modern, abnormal weather conditions. It suffices to say that the climate of the region has long been cold and icy.

Cape Espenberg was inhabited intermittently for over 4000 years (Harritt 1994; Tremayne 2015) due to

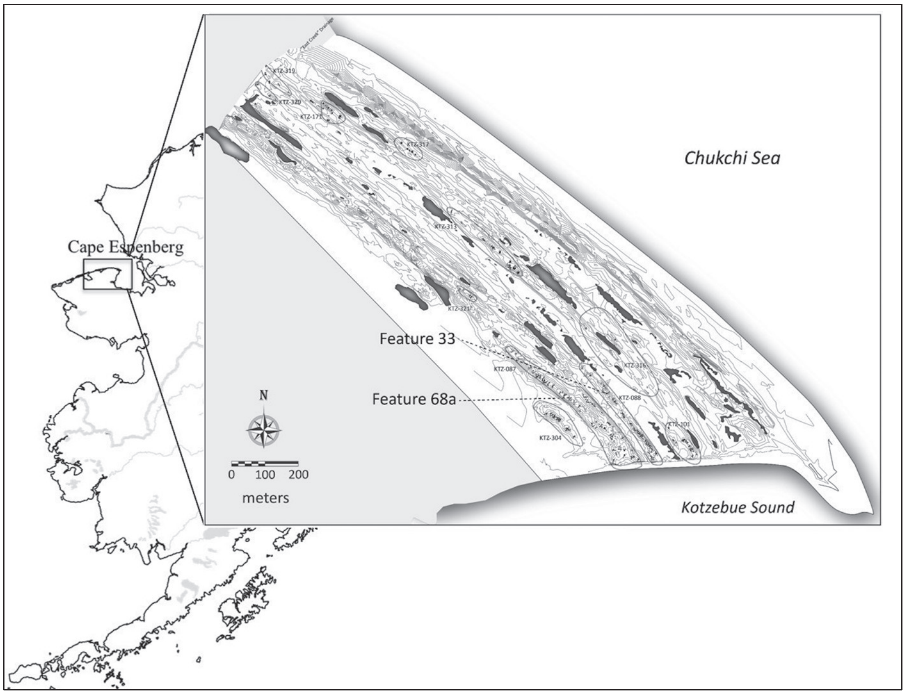

Figure 1: Cape Espenberg (adapted with permission from John Darwent, University of California, Davis, 2015, unpublished).

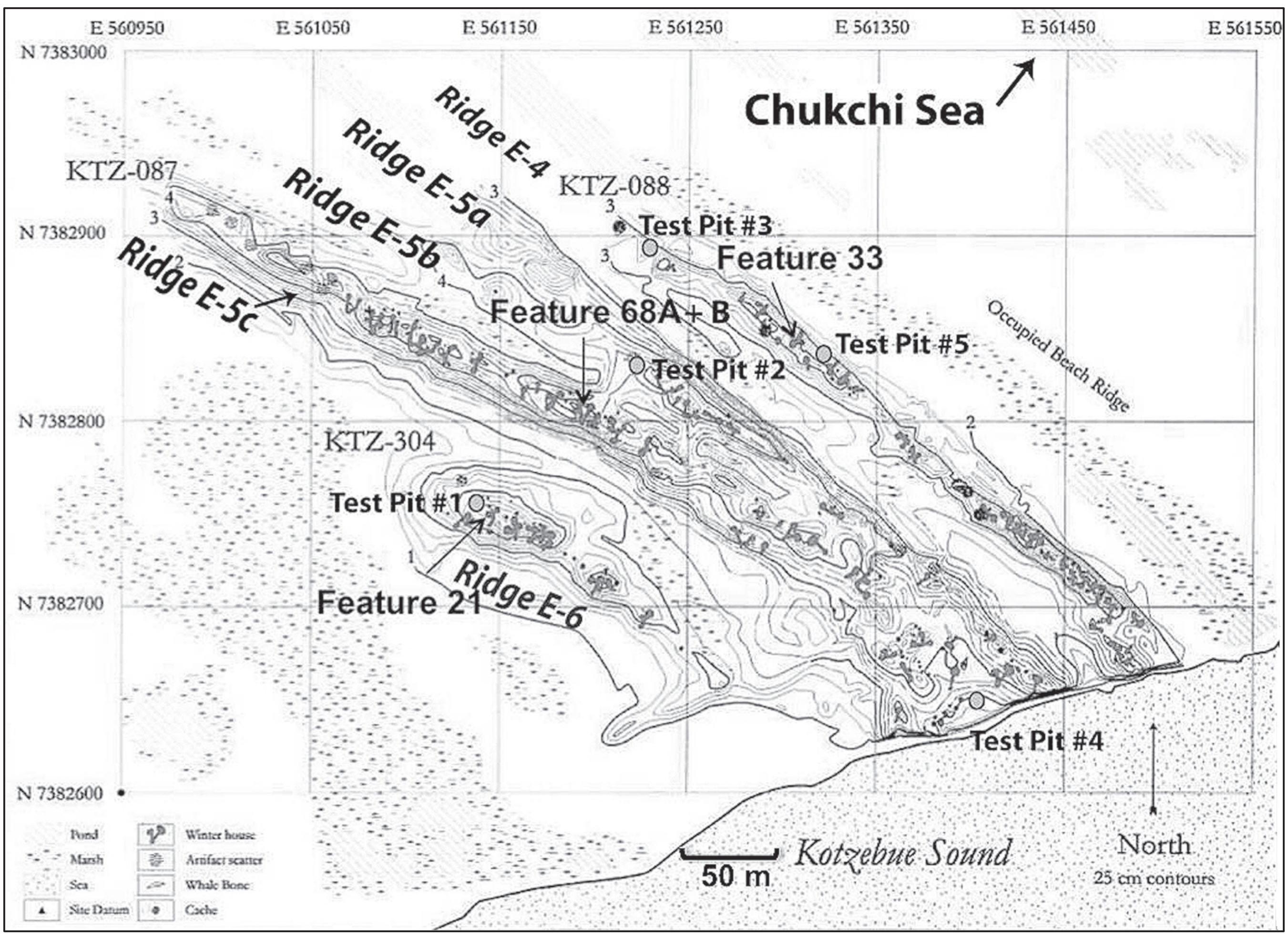

Figure 2: Cape Espenberg site map (adapted with permission from John Darwent, University of California, Davis from Hoffecker and Mason 2010).

fluctuating resource abundance. Precontact occupants left behind cache pits, house depressions, burials, and artifact scatters, which can be seen in Fig. 2 (Harritt 1994; Mason 1990; Schaaf et al. 1988). After AD 1200, clusters of Thule house ruins occur across localized areas on several beach ridges for hundreds of meters (Mason and Gerlach 1995:116), suggesting a dense occupation (Darwent et al. 2013; Mason and Bowers 2009).

The Thule culture (ca. AD 1100–1700) is the most recent complex of the Northern Maritime tradition, which developed around 1000 years ago in the Bering Strait, emerging from antecedent Alaskan Birnirk and Siberian Punuk cultures (Mason 2016). Unlike earlier cultures, the Thule economy was defined by whaling, and they formed relatively large communities to coordinate whale hunts (Harritt 1995; Mason 1998). During the Thule era, whaling surpluses created hierarchies (Whitridge 1999) because the *umialik* (whaling captain) received a larger share of captured whales. This surplus of meat and blubber could be traded for exotic and prestigious goods (e.g., iron) and translated into social power (Sheehan 1995, 1997:179–180, 184; Whitridge 1999).

At Cape Espenberg there are bowhead whale (*Balaena mysticetus*) remains atop dunes and within houses. However, it is not clear if whaling was possible at Cape Espenberg. Today, Kotzebue Sound does not attract large baleen-type whales, only belugas (*Delphinapterus leucas*; Darwent et al. 2013; Hoffecker and Mason 2011). Any bowhead whale remains may originate from beached animals. After AD 1700, the number of late Western Thule/Kotzebue-era type houses at Cape Espenberg decreased. This population decline suggests that the spit had become less attractive, leading to its ultimate abandonment (Burch 1998), perhaps as a result of the sociocultural and resource changes mentioned above.

THULE FUEL USE

Precontact northwestern coastal Alaskans typically burned bone, sea mammal oil, and wood. With the exception of the Ipiutak (ca. AD 200–900), who apparently exclusively burned wood (Larsen 2001; Larsen and Rainey 1948; Mason 2013), precontact Arctic Alaskans relied primarily on oil lamps for cooking and heating (Burch 2006; de Laguna 1940). Alix (2005) suggests that wood was essential for many purposes but not usually as fuel. Sometimes wood was burned only for specific activities (e.g., smoking fish). When Thule people burned wood, they used both larger-diameter driftwood and smaller local shrubs and twigs (Alix 2009a:192). Finally, Thule people also burned significant quantities of bone, which appears to have been an important fuel source at other Birnirk and Thule sites such as Walakpa and Uivvaq (Alix 2003, 2008).

FEATURES 68A AND 33

For this study I examined anthracological collections from two houses excavated in the summer of 2010. Located on the E-5a and b dune ridges, Feature 68A is part of the KTZ-087 site complex, which includes 93 features with 39 house ruins extending for 400 m across the spit within six discrete areas (Mason et al. 2008:5). Feature 33 lies on the more seaward E-4 dune within site KTZ-088, which contains over 40 features, including 27 house depressions. Neither excavated house shows evidence of postoccupational disturbance, and organic preservation was excellent.

These two houses are typical late Western Thule dwellings (Friesen and Betts 2006; Lee and Reinhardt 2003). Both Feature 68A and Feature 33 were semisubterranean sod dwellings with wooden frames, likely occupied during the winter months. Figs. 3 and 4 are maps of Feature 33 and Feature 68A, respectively. Each house has a sunken entrance tunnel, a main room, and presumably rear sleeping platforms (Feature 68A's main room was not excavated fully). Two burned features, referred to as Feature 68A-1 (F68A-1) and Feature 33-1 (F33-1), were found near each house.

These houses differ slightly. First, Feature 68A has a south-facing tunnel entrance and Feature 33 has a north-facing tunnel entrance (Hoffecker and Mason 2010). This difference could indicate changing climatic conditions such as the direction of prevailing winds, season of occupation, or changing cultural preferences for tunnel orientation. Feature 68A's entrance tunnel is long, at nearly 6 m in length. In comparison, Feature 33's tunnel is only 4 m long. Second, the main living area in Feature 33 was about 7 m^2, but the full extent of Feature 68A's partially excavated living area is unknown. From what has been excavated, Feature 68A's living area appears to be slightly smaller than Feature 33's living area. In the Kotzebue Sound region, main living areas typically contained elevated rear sleeping platforms where most household activities took place by the light of an oil lamp (Anderson 1984; Ford 1959; Lee and Reinhardt 2003).

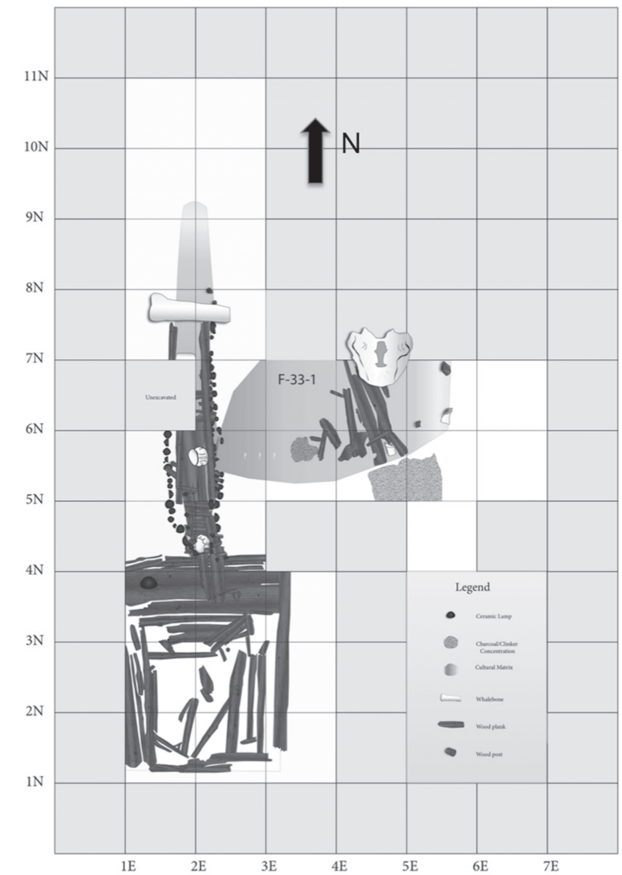

Figure 3: KTZ-088 Feature 33 showing all levels (adapted with permission from John Darwent, 2010, unpublished). Each square represents 1 m².

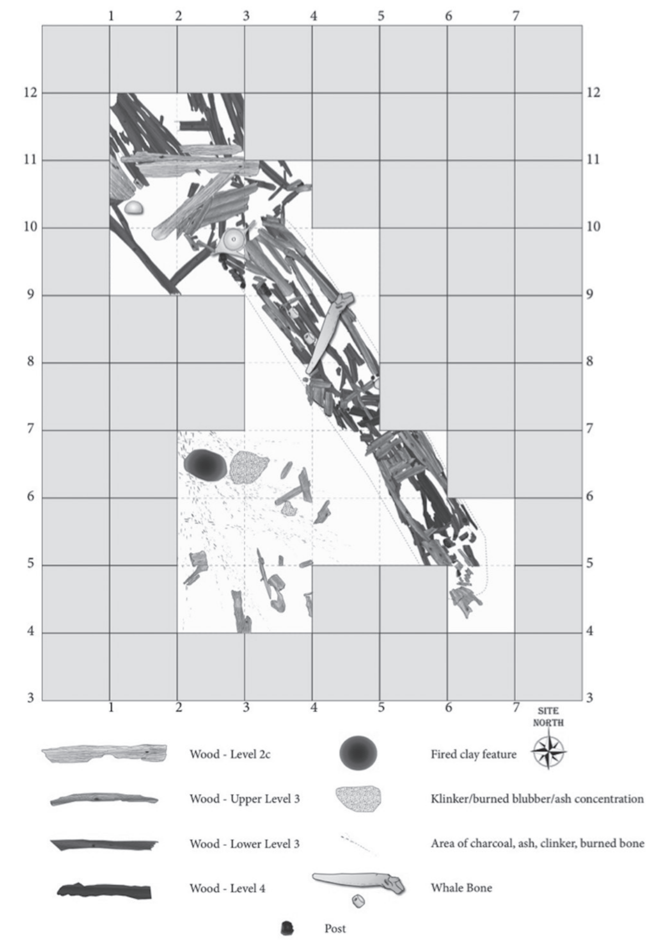

Figure 4: KTZ-087 Feature 68A showing all levels (adapted with permission from John Darwent, 2010, unpublished). Each square represents 1 m².

Thule houses used oil lamps inside the main room for cooking, heating, and lighting, but internal hearths or external kitchens with open fires were not uncommon. There are examples from Cape Krusenstern, located just across the Kotzebue Sound from Cape Espenberg (Giddings and Anderson 1986), and along the Kobuk River (Giddings 1952a). The hearth-like features in Features 33 and 68A are termed "burned features" because they are outside the main living areas and their function is uncertain. They both contain high concentrations of sea mammal oil-cemented sand (clinker), charcoal, and small burned bones.

F33-1 has been interpreted as an unattached but covered kitchen area (Hoffecker and Mason 2010), but the roof structure is unknown. F33-1 resembles some postcontact and late precontact northern Alaska houses where food was cooked in a separate, connected kitchen alcove constructed with earthen walls and wood or whale-scapula roofs (Friesen and Betts 2006; Lee and Reinhardt 2003). F68A-1 is an unconnected burned area to the west of the main room with no architectural elements such as walls, wood frames, or posts. F68A-1 may have been a separate tent-covered outdoor summer cooking or ceramic firing area. It might have been a ceramic firing pit because it appeared as a reddish, possibly burned, clay-covered area (Darwent et al. 2013:444).

Dates on the two houses come from broken caribou bones (*Rangifer tarandus*), the outer ring of architectural wood elements, and short-lived plant material (see Table 1). These dates point to a late Western Thule period occupation. A caribou rib from Feature 33 dates to 20 ± 40 RCYBP (Beta-286170; bone collagen). The outer ring of a spruce (*Picea* spp.) tunnel post dates to 80 ± 30 RCYBP (Beta-343354) or within the same age ranges (2σ 1729–1920 cal AD 1730–1926 cal AD, respectively). The absence of European trade goods suggests that Feature 33 is a precontact late Western Thule occupation dating to the

Table 1. Radiocarbon dates by house feature.

Feature	Lab Number	RCYBP (1σ)	Cal BP (2σ)	Material
33	Beta-286170	120 ± 40 BP	AD 1675–1778 (36.1%) AD 1799–1942 (69.3%)	Bone collagen
33	Beta-343354	130 ± 30 BP	AD 1678–1764 (32.6%) AD 1800–1940 (62.8)	Outer ring of tunnel post *Picea* spp.
68A	Beta-286171	250 ± 40 BP	AD 1514–1805	Bone collagen
68A	Beta-286172	360 ± 40 BP	AD 1450–1635	Bone collagen
68A	AA97493	355 ± 27 BP	AD 1454–1634	*Rangifer tarandus* (F68A-1)
68A	OS-96067	395 ± 15 BP	AD 1444–1614	*Empetrum nigrum* (tunnel floor)
68A	Beta-347937	480 ± 30 BP	AD 1410–1450	Tunnel bottom crosspiece *Picea* spp. outer ring

late seventeenth to late eighteenth century. Feature 68A is slightly older than Feature 33. Multiple radiocarbon dates on caribou bones (140 ± 40 RCYBP, Beta-286171; 260 ± 40 RCYBP, Beta-286172; 355 ± 27 RCYBP, AA-97493; 395 ± 15 RCYBP, NOSAMS-96067) combine to date Feature 68A's occupation to the Intermediate Kotzebue period between AD 1495 and AD 1614.

METHODS

FIELD METHODS

After removing overburden and fill layers, excavators employed blanket scatter sampling, collecting one liter of sediment from each 10 cm layer for every 1 m^2 unit. This sampling method allows for comparison between contexts and houses (Pearsall 2015). For F33-1 the crew collected a 100% pinch or bulk sample. We did not take a similar bulk sample from F68A-1 because the burned area was not immediately recognized in the field. In total, excavators collected 237 soil samples from the cultural layers of Features 33 and 68A, each sample being approximately one liter (save for larger bulk samples).

Following sampling, we separated botanical and anthracological remains from the soil matrix using flotation. Excavators floated samples on site using a flotation system design by Shelton and White (2010). We poured sediment samples into the top tank, where we agitated them by hand, spraying water pumped from the bottom tank using a bilge pump. The light fraction was filtered through and collected in 250 μ mesh bags attached to the tank's spout. Following processing, all paleobotanical materials were sent to the Alaska Quaternary Center at the University of Alaska Fairbanks.

LABORATORY METHODS

I split occupation-level samples that were still large and sandy after initial field flotation. I hand-sieved others to remove extra sand, using 450 μ and/or 250 μ mesh screens. I sieved all samples at 250 μ and added a 450 μ screen when a sample was particularly organically rich. To further facilitate the sieving process, I disaggregated some hand-sieved samples with a 5% potassium hydroxide (KOH) solution.

I selected 37 cultural samples—a total 22.5 liters of soil—for analysis from the tunnel, burned features, and main living areas. Each sample yielded bountiful, well-preserved paleobotanical remains. I analyzed at least one sample from most 1 m^2 units of the occupation layer that was directly atop the houses' wooden floors. When possible, to make samples representative and unbiased, I randomly selected 50 pieces of charcoal for identification. Low woody taxa biodiversity in the Arctic and Subarctic means that a minimum of 50 charcoal specimens from any sample is typically sufficient to capture the full extent of woody taxa diversity (Mooney 2013:60). In total, I examined 1617 charcoal fragments from the sampled cultural units.

I initially sorted samples under low (10x) magnification, counted charcoal found in sorted samples, and then identified these charcoal fragments using a high-powered reflected light microscope (100x to 500x). For identification, I broke charcoal to view the cross, tangential, and radial sections. I observed microscopic anatomy and structure across these three sections, which typically allowed for identification at least to the genus level. Comparative materials and reference manuals aided identification (see Benkova and Schweingruber 2004; Hoadley 1990; Panshin and de Zeeuw 1980).

I also observed growth curvature to separate small-diameter local vegetation from nonlocal larger-diameter wood using a method proposed by Marguerie and Hunot (2007), who distinguished three categories of ray curvature (small, medium, and large). Although there are techniques that allow for more precise wood diameter estimates, this method was sufficient for my purposes (Dufraisse and Garcia Martinez 2011) since my goal was to compare the ratio of local growth (twigs) to nonlocal growth (driftwood). Noting the presence or absence of bark and pith in charcoal specimens with tight curvature can help determine if small-diameter (< 5 mm) specimens originated from local shrubby vegetation. Only small-diameter specimens with intact bark and pith are considered to originate from local vegetation. This distinction is important, as some small-diameter fragments occasionally survive the driftwood deposition process but not often with bark attached (Alix 2003).

The absence of definitive hearth features clearly inside either structure means that charcoal fragments found in the living areas and tunnels of both houses are secondary deposits. These contexts represent long-term firewood selection and better reflect what wood was available on the contemporary landscape. In contrast, because burned features such as F33-1 and F68A-1 were likely cleaned between uses, the charcoal therein represents only the last few burning episodes. Such features can give an idea of short-term firewood selection (Byrne et al. 2013; Heinz and Thiébault 1998).

I employed statistical tests to interpret differences between contexts and houses. The number of observations and individual taxa counts, however sufficient for capturing woody taxa diversity, proved inadequate for statistical analyses. Lumping identified charcoal specimens into two larger categories, angiosperm or gymnosperm (hardwood and softwood), increased test power. These categories reflect distinctions modern Alaskans make between coniferous and deciduous woods (Alix and Brewster 2004; Anderson et al. 1988; Deo-Shaw 2008). In northwestern Alaska, strong evidence for cultural continuity from Thule times onward makes ethnographic analogies useful (Anderson 1984; Collins 1937; Mathiassen 1927; Taylor 1963).

Both categories contain multiple genera. The gymnosperm category contains likely spruce (*Picea/Larix* cf. *Picea* spp.), indeterminate spruce/larch (*Picea/Larix*), likely larch (*Picea/Larix* cf. *Larix* spp.), and undifferentiated gymnosperm charcoal. The angiosperm category contains alder (*Alnus* spp.), birch (*Betula* spp.), a locally growing heather family (Empetraceae)—most likely crowberry (*Empetrum nigrum* spp.)—willow (*Salix* spp.,) indeterminate willow/poplar, (*Salix/Populus*), poplar (*Populus* spp.), and undifferentiated angiosperm charcoal. Note that several genera are grouped because they are difficult to distinguish microscopically. For instance, spruce and larch are quite difficult to separate (Anagnost et al. 1994; Bartholin 1979), especially when ray tracheids are poorly preserved. Distinguishing willow from poplar can also be challenging (Benkova and Schweingruber 2004). Even birch can be hard to differentiate from willow at times (Marquer et al. 2012).

To select the correct statistical tests, I had to test for normality. Normality tests compare observed samples to a theoretical probability distribution. According to a Kolmogorov-Smirnov Test of Normality at the 0.05 confidence level, these anthracological data were not normally distributed. Therefore, nonparametric tests were more appropriate. Nonparametric tests do not assume normality and make fewer assumptions about the nature of a sample, making them more robust—a quality needed for this relatively small sample size.

Ultimately, I chose Mann-Whitney U and Kruskal-Wallis tests to contrast gymnosperm and angiosperm abundance between the two houses and their contexts. Mann-Whitney U tests against the null hypothesis that two samples originate from the same population and evaluates whether one population has larger values than the other (Walker and Shostak 2010). Thus, I used nonparametric Mann-Whitney U tests to explore differences between angiosperm and gymnosperm abundance by comparing paired contexts for both houses. For comparisons between two or more groups (e.g., multiple domestic contexts) I employed Kruskal-Wallis tests. Kruskal-Wallis tests are similar to Mann-Whitney U tests except they are used when there are more than two independent populations. Kruskal-Wallis tests, however, produce omnibus test statistics, and post-hoc tests were necessary to determine which populations varied (Walker and Shostak 2010).

Table 2. Charcoal taxa counts and percentages by house feature.

ID	Sum	Percent	Feature 33	Feature 68A
Alder (*Alnus* spp.)	2	0.1%	0	2
Angiosperm, undifferentiated	132	8.2%	79	53
Birch (*Betula* spp.)	14	0.9%	13	1
Crowberry (*Empetrum nigrum*)	2	0.1%	0	2
Gymnosperm, undifferentiated	83	5.1%	33	50
Likely larch (*Picea/Larix* cf. *Larix* spp.)	40	2.5%	31	9
Likely spruce (*Picea/Larix* cf. *Picea* spp.)	981	60.7%	426	555
Maybe crowberry (*Empetraceae* spp.)	11	0.7%	9	2
Poplar (*Populus* spp.)	29	1.8%	15	14
Poplar or willow (*Populus/Salix*)	40	2.5%	27	13
Willow (*Salix* spp.)	230	14.2%	132	98

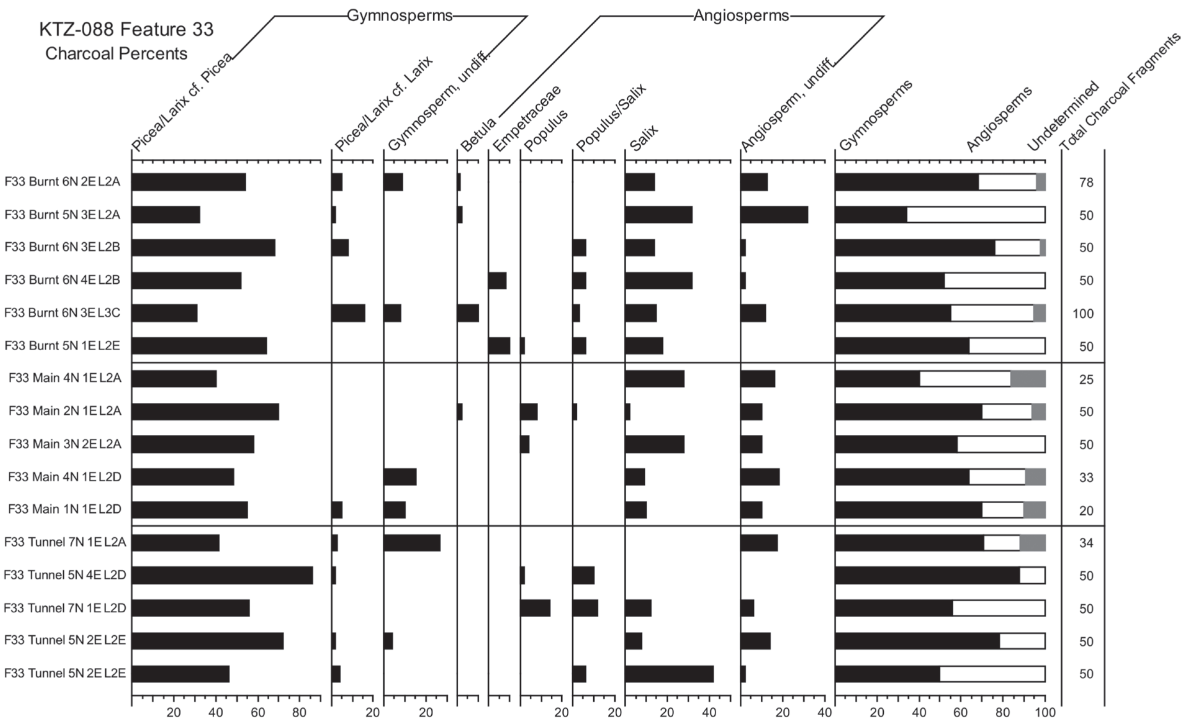

Figure 5: Charcoal taxa in Feature 68A by unit, level, and context.

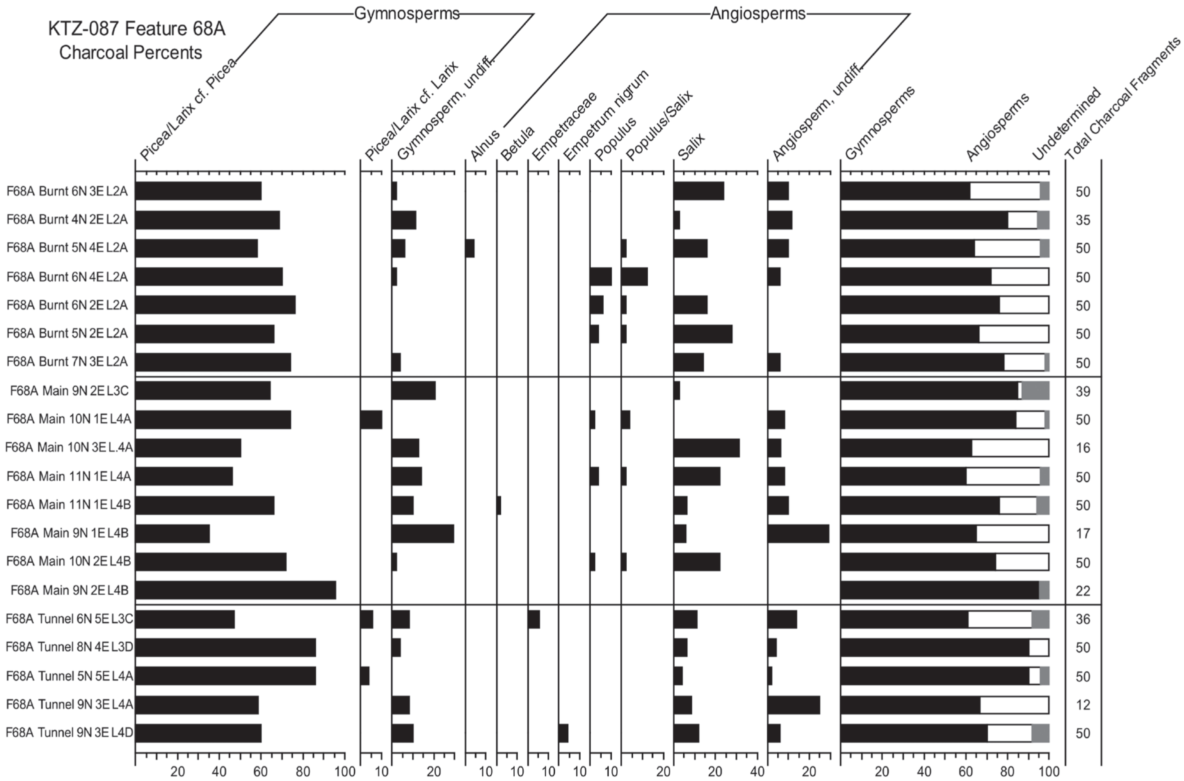

Figure 6: Charcoal taxa in Feature 33 by unit, level, and context.

RESULTS AND DISCUSSION

QUALITATIVE ANALYSES

Due to preservation issues I could not identify all specimens to the genus level. A minority (16%) of specimens examined were too small, vitrified, occluded with foreign substances, or decayed to be identified to the taxa level. Undifferentiated angiosperms, which could be alder, willow, poplar, or birch, comprised 8% of the total. Undifferentiated gymnosperms—either spruce or larch—comprised 5% of the total. Fifty-three very poorly preserved fragments (3%) could not be identified at all. Unfortunately, such preservation issues are common in anthracological samples.

Each identified woody taxon must be examined and compared against its natural abundance in driftwood accumulations. Table 2 shows the number of identified woody taxa—including undifferentiated angiosperms and gymnosperms—by house and context. Figures 5 and 6 present the same data but in Tilia graphs. These data are compared to Alix's (2005:89) driftwood data. Presumably, a divergence of anthracological taxa quantities from natural driftwood abundance evidences anthropogenic wood selection. There are multiple lines of evidence that the ratio of woody taxa in northwestern Alaska driftwood accumulations has not changed since Thule times (Alix 2001, 2005:85–86, 2009b; Higuera et al. 2009). Thus, uniformitarian principles apply.

Perhaps the best way to understand precontact driftwood abundance is to use Claire Alix's 2005 driftwood study, which set the standard by identifying driftwood at a number of sites on Alaska's northwestern coast. Alix's sample size at each location is large enough to capture the low biodiversity of the region's driftwood taxa, and she sampled driftwood accumulations over a large area. Sampling error is unavoidable, but Alix's survey is more than satisfactory. The following analysis compares the amount of wood charcoal at Cape Espenberg to the amount of different driftwood taxa identified by Alix.

The first taxon to be examined is alder, which is the rarest taxon recovered at 0.1% of the total. Alix (2005:89) found alder driftwood at two Alaskan sites only (Nunavak and Wainwright), where it constituted 4–7% of the total. The inhabitants of Cape Espenberg burned alder in amounts smaller than its natural abundance as driftwood. Where it grows, various Alaskan groups consider hot, clean, and slow-burning alder to be decent firewood. Some postcontact Iñupiat individuals cited that they preferred alder over cooler-burning willow (Anderson et al. 1988; Burch 2006; Deo-Shaw 2012). However, alder driftwood is particularly susceptible to decay, rotting, and sinking in rivers before reaching the sea (Alix 2002). As driftwood, alder is rare.

Birch driftwood is also rare in northwestern Alaska. Birch decays quickly, and this is accelerated by the moisture trapped beneath its waterproof bark (Alix 2005:91, 2009b:189). If it is not quickly encased in ice, birch sinks within six months of entering the driftwood cycle, which, from start to finish, can last three to six years (Deo-Shaw 2012; Dyke et al. 1997; Hole and Marcias-Fauria 2017; Tremblay et al. 1997). Then, even in the unusual instances where birch survives the driftwood cycle, its bark prevents it from drying properly, making it unsuitable for firewood (Alix 2004; Alix and Brewster 2004).

Thule inhabitants, however, burned birch in keeping with its natural abundance. Birch comprises 1% of the charcoal assemblage at Cape Espenberg and constitutes 0–3% of modern northwestern Alaska driftwood accumulations (Alix 2005). Elsewhere in Alaska, highly energetic, slow-burning birch is considered excellent firewood (Alix 2001; Wheeler and Alix 2004), although some groups shun it because it is too smoky (Osgood 1958:163). Its desirable combustion properties may have motivated Cape Espenberg's inhabitants to select birch whenever it was dry.

Crowberry is the only exclusively local woody taxon charcoal, comprising 0.1% of the sample. In contrast, uncharred crowberry seeds, leaves, and stems dominate the macrofossil assemblages at both houses. A full 2061 of the 2589 macrofossils identified (80%) from cultural contexts were crowberry (see Crawford 2012 for macrofossil analysis). In ethnographic times crowberries were eaten and used as medicine, and they may have been used similarly by Thule people (Jones 2010; McIntosh 1999). Crowberry was infrequently burned, however, likely because it is a procumbent shrub. It is most common in both burned areas, and experiments demonstrate that using crowberry twigs as kindling results in its preservation (Vanlandeghem et al. 2015). In addition to serving as kindling, crowberry twigs, like twigs in general, could have been added to an established fire to help control flame height, heat output, ember brightness, and cinder expulsion (Dufraisse 2006; Dufraisse and Garcia Martinez 2011).

Alix (2005) classified 5–6% (n = 5 and 6) of the Alaska driftwood she surveyed as "likely larch." At Cape Espenberg only 3% of analyzed charcoal specimens were identified as probable larch. Larch is energetic firewood compared to other taxa (e.g., spruce), and its resiliency and flexibility make it well-suited for implement manufacture (Alix 2004). Larch appears to be versatile as fuel and otherwise. Perhaps its low occurrence as charcoal means that Thule inhabitants chose to save larch for other purposes.

Spruce was the most important firewood taxon. It dominates both the anthracological record at Features 68A and 33 (63%) and northwestern Alaska driftwood assemblages (40–69%) (Alix 2005:89; Alix and Brewster 2004:7). Cape Espenberg's Thule inhabitants burned spruce on the high side of regional values because it is common, energetic, and clean burning. Alaskans today still select spruce specifically when they desire such combustion properties (Anderson et al. 1988; Deo-Shaw 2008). Spruce was valuable for other purposes as well: in Alaska, Birnirk and Thule people predominantly chose spruce for carving (Alix 2001, 2009b).

At 15% of the total, willow is the second most common taxon at Cape Espenberg, a distant second to spruce. Willow comprises 6–23% of sampled Alaska driftwood accumulations, so the quantity of willow charcoal at Cape Espenberg matches its natural abundance. Willow, however, is cool burning (Alix 2005; Mooney 2013), which could suggest that its state was more important than its taxon-specific properties. Or perhaps willow's energetic output was not noticeably lower than that of more energetic taxa.

There is less poplar charcoal at Cape Espenberg (2%) than poplar driftwood today (20–39%). Poplar driftwood is common and second only to spruce in some places (Alix 2005). Feature 33 had poplar structural elements (Méreuze 2015) as did structures from the Coop site (Alix 2009b). Thus, the lack of poplar charcoal cannot be attributed to the lack of poplar driftwood. Additional evidence supports this interpretation. First, the composition of Alaska's boreal forest has changed little in the last 4000–6000 years (Alix 2009b; Higuera et al. 2009). This is the origin of most of northwestern Alaska's driftwood, so if the boreal forest is unchanged, so are driftwood assemblages.

Second, changing ocean currents and/or climatic conditions would have altered the ratio of all taxa, not just poplar. For instance, shifting gyres can change the proportion of Alaskan and Siberian taxa deposited (Alix 2005:85–86). However, Siberian taxa like larch and pine are rare at Birnirk and Thule sites just as they are today. There is little evidence that gyres directing the flow and direction of driftwood have undergone any significant changes since Thule times (Alix 2001, 2005).

Finally, no woody taxon is significantly more vulnerable to taphonomic processes. The law of fragmentation states that, with time, taphonomic processes reduce differential preservation related to taxa specific characteristics (Byrne et al. 2013; Théry-Parisot et al. 2010). Thus, differential decay is probably not a major source of bias.

Human preference best explains the lack of poplar (Théry-Parisot et al. 2010). However, state-specific properties were often more important than taxon-specific properties. Some groups did/do not consider taxon-specific characteristics because they did not categorize wood by species (Théry-Parisot 2002). Firewood categories and preferences are not universal. For instance, the Greenlandic Inuit named driftwood according to its purpose, and Alaskans on the north coast may sometimes categorize firewood as either *uumak* (green wood) or *kiruk* (dry, dead wood) (Webster and Zibell 1970:101).

At Cape Espenberg, however, Thule people may have shunned poplar because of its taxon-specific combustion properties. The Iñupiat today consider poplar to be poor firewood (Alix 2005:94; Burch 2006:187). They dislike burning poplar in their woodstoves because it is cool and fast burning, excessively smoky, and sparky. It is seen as the firewood of last resort, though some Alaskans employ this smokiness for specific, strictly outdoor activities like repelling mosquitoes or smoking fish (Burch 2006:187; Deo-Shaw 2008:55). Because there is long-standing cultural continuity in this region, it is possible that Thule people also ignored poplar because of its lackluster combustion properties.

Poplar is the only taxon that was collected in quantities far outside of its natural abundance as driftwood. Otherwise, Thule inhabitants chose taxa in quantities close to their natural abundance, selecting wood primarily according to its state, length, and caliber while ignoring wood with high humidity or other undesirable traits. Taxon-specific combustion properties were often secondary considerations, but it was the combination of state- and taxon-specific properties that made any taxon more or less desirable.

QUANTITATIVE ANALYSES

Comparing houses with statistical analyses revealed categorical differences. A Kruskal-Wallis test indicates that at the 0.05 significance level, there are more angiosperm fragments in Feature 33 and more gymnosperm fragments in Feature 68A (p = < 0.001) than expected. More precisely, an independent samples Mann-Whitney U test shows that F33-1 contained significantly more angiosperm specimens than F68A-1 (p = 0.022). Another independent samples Mann-Whitney U test revealed that Feature 33 contained significantly more local vegetation (twigs) than Feature 68A (p = 0.01). Post-hoc tests show that Feature 33's living area contained more charcoal originating from local growth than Feature 68A's living area (p = 0.045). F33-1 also contained more twigs than F68A-1, but the relationship is not quite statistically significant (p = 0.062). Refer to Figs. 7 and 8 for a visual representation of this pattern.

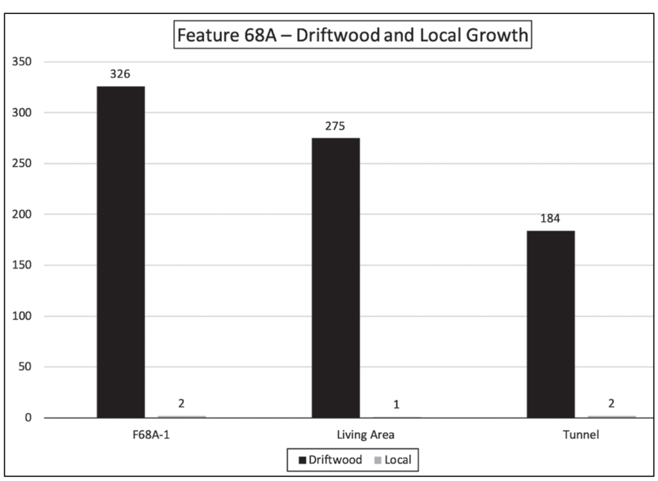

Figure 7: Comparing growth curvature counts by context in Feature 68A.

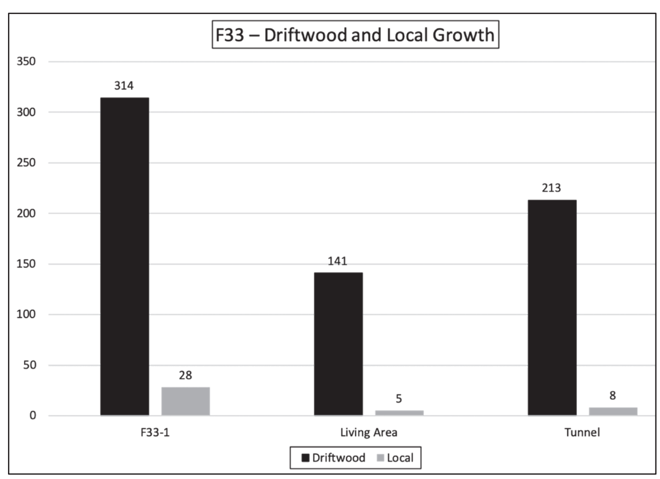

Figure 8: Comparing growth curvature by context in Feature 33.

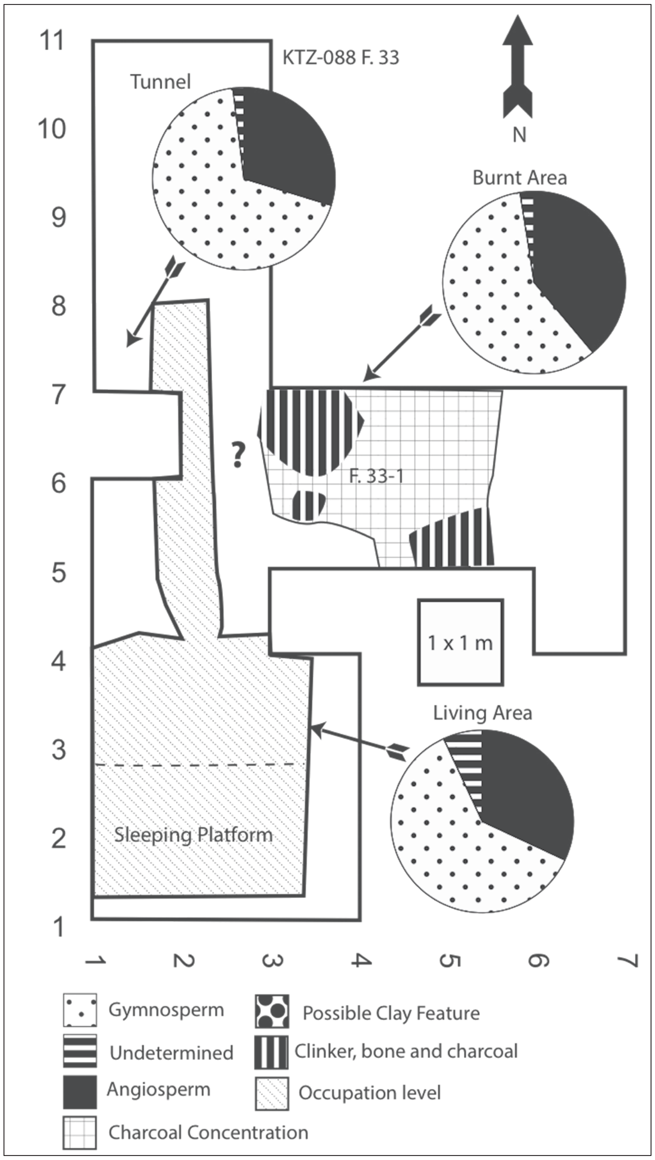

Figure 9: Angiosperm and gymnosperm charcoal fragments in Feature 68A. Numbers grid measures 1 m².

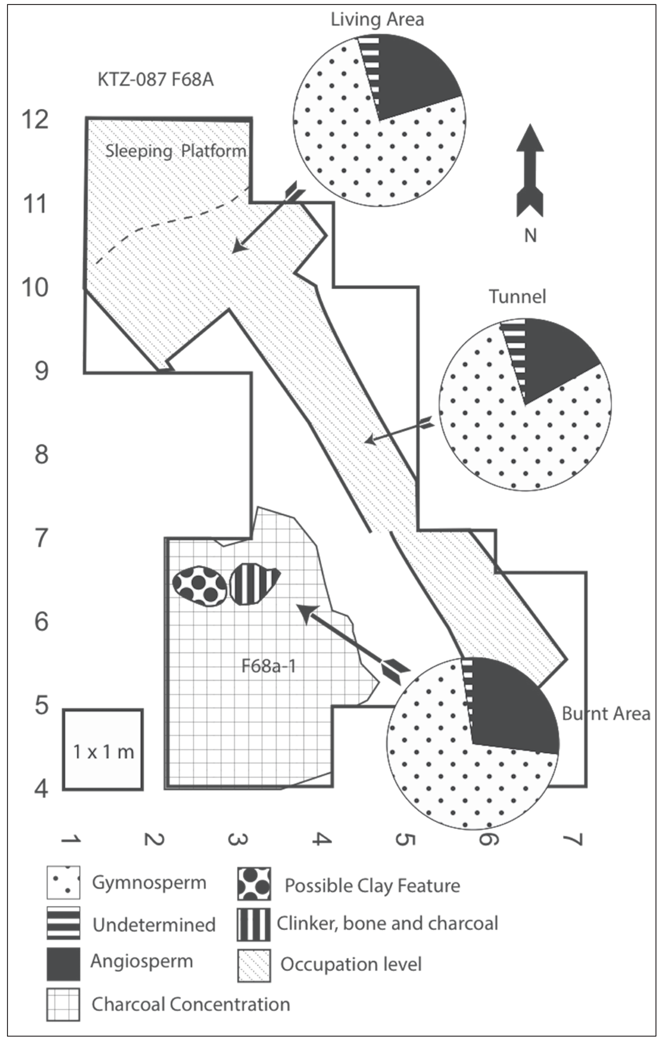

Figure 10: Angiosperm and gymnosperm charcoal fragments in Feature 33. Numbers grid measures 1 m².

Other statistical tests were performed to compare contexts within rather than between houses. In Feature 68A, a Kruskal-Wallis test shows no statistically significant differences between gymnosperm and angiosperm charcoal counts when comparing the different domestic contexts (p = 0.91 and 0.742 for angiosperm and gymnosperm counts, respectively). All contexts within Feature 68A are dominated by gymnosperm taxa (overwhelmingly spruce), which comprise 72% of the total burned feature, 79% of the living area, and 82% of the tunnel assemblage. As such, the percentage of gymnosperm charcoal in Feature 68A is higher than the percentage of gymnosperm driftwood in northwestern Alaska (Alix 2005). Figure 9 shows the breakdown of angiosperm wood versus gymnosperm wood by context in Feature 68A.

I performed identical statistical tests for Feature 33. When using an independent sample Kruskal-Wallis test I found no statistically significant differences between contexts (p = 0.92 and 0.193 for angiosperms and gymnosperms, respectively). Like in Feature 68A, Feature 33's charcoal assemblage as a whole is dominated by gymnosperms. Every context in Feature 33, however, has fewer gymnosperm specimens than Feature 68A. For comparison, gymnosperm taxa comprise 60% of the burned feature, 66% of the living area, and 70% of the tunnel. The abundance of gymnosperm charcoal in Feature 33 exceeds the abundance of gymnosperm driftwood in northwestern Alaska. Figure 10 is a map of Feature 33 that shows the ratio of angiosperm to gymnosperm wood within each context.

Comparing contexts within Feature 68A and Feature 33 reveals no significant differences in terms of angiosperm and gymnosperm abundance. This suggests that inhabitants engaged in a consistent, long-term pattern of driftwood taxa selection. Both houses and all contexts are dominated by spruce, likely for the reasons discussed above.

At each house the percentage of gymnosperm charcoal (64% at Feature 33 and 77% at Feature 68A) exceeds the percentage of gymnosperm logs in northwestern Alaska driftwood accumulations (56% on average). Thule inhabitants likely accumulated higher quantities of gymnosperm logs by exploiting successive driftwood deposition episodes. If they preferred gymnosperms, Thule foragers would have selected spruce and larch before collecting less desirable angiosperm wood. If they had enough bone, oil, and wood fuel—perhaps including stockpiled gymnosperm wood—they could ignore some or all angiosperm driftwood. By repeating this over the course of multiple driftwood deposition episodes, collected gymnosperm wood would exceed natural abundance. Angiosperm wood, on average, comprises 44% of northwestern Alaska driftwood assemblages, but appears as charcoal in lower amounts in Feature 33 (36%) and Feature 68A (23%). This departure from natural driftwood abundance suggests anthropogenic selectivity.

F33-1 has less gymnosperm charcoal than F68A-1, which could suggest functional differences between the burned features. F33-1 contains more angiosperms, twigs, and burned bones than F68A-1. A raw count shows that the number of charcoal and bone fragments is similar (622 and 544 pieces, respectively), but it is difficult to know the original ratio because charcoal is more susceptible to taphonomic processes (e.g., trampling) than bone. F68A-1 contained a significant quantity of burned bones as well, but since we did not take a bulk sample from F68A-1, the bone found in both burned features cannot be compared directly.

To understand fuel management practices, it is important to determine whether bone was burned intentionally. Burning bone is an efficient way to eliminate waste, and bones can fall into fires inadvertently. Unless bone was added intentionally as fuel it cannot be considered as such. In essence, when there are large amounts of bone present in contexts that can be linked to an activity, bone is considered as fuel (Marquer et al. 2010; Marquer et al. 2012). While F33-1 may or may not have been used for cooking, the large quantity of burned bone fragments suggests that bone was added purposefully.

Bone was likely introduced to F33-1 and F68A-1 because it is a superb fuel source that is about as energetic as green wood. Fresh, greasy bones are especially hot burning because animal fat burns at about twice the temperature of most woods (Beresford-Jones et al. 2010:2808; Deo-Shaw 2008:59). Even so, bone fuel has several drawbacks. First, it requires high temperatures (350–380°C) to ignite, which necessitates kindling (Beresford-Jones et al. 2010). Plus, it is a poor heat conductor that does not produce embers. Bone is better suited for lighting, drying, or curing, not indirect cooking or nocturnal heating. Additionally, combining wood and bone results in slightly lower temperatures, but these cooler burning fires may have been safer (Marquer et al. 2010; Théry-Parisot 2002). Burning bone and wood together is also an effective way to conserve fuel because the correct ratio of bone to wood (80% bone and 20% wood is ideal) increases burn time (Théry-Parisot 2002:1418).

While there is a widespread notion that the addition of bone fuel implies firewood scarcity, this is not always true (Cook 1969:277; Hoffecker 2005; Marquer et al. 2010:2735). The main support for such an argument is an apparent paucity of wood charcoal. Taphonomic processes (e.g., freeze/thaw cycles, bioturbation), however, affect charcoal more intensely than bone (Marquer et al. 2010; Marquer et al. 2012). Thus, it is difficult to accurately estimate the original proportion of bone to firewood. In short, the quantity of burned bone does not prove that driftwood was less abundant during the occupation of Feature 33. Instead, occupants may have desired bone's combustion properties and/or wanted to conserve wood.

The inhabitants of Feature 33 also burned more local vegetation (twigs) in the living area and burned feature. Twigs can be used to manage internal fires as outlined above (Dufraisse and Garcia Martinez 2011), and the addition of twigs to F33-1 could have served as kindling and/or helped control the fire. Secondary deposits of twiggy charcoal in the living area of Feature 33 evidence their addition to multiple anthropogenic fires.

The inhabitants of Feature 33 were burning more bone and less desirable angiosperm wood, but this is not likely due to driftwood decline and scarcity. With a decline in driftwood deposition, inhabitants would have exhausted preferred gymnosperm firewood sooner and burned more angiosperm firewood. Eventually they would have resorted to burning poplar, whatever its drawbacks. Thus, if driftwood was scarce, there should be more poplar charcoal. Feature 33 and Feature 68A contain about the same amount of poplar, however. This suggests that Feature 33's inhabitants could ignore poplar because they had enough wood, bone, and oil.

Seasonality could explain the idiosyncrasies of F33-1. Since the Birnirk and Thule era (at least) until the recent past, the Iñupiat and their ancestors occupied semisubterranean houses on the coast from fall to spring. With the return of warmer weather these dwellings became warm, smelly, damp, and flooded. Most people evacuated their winter dwellings and adopted a more mobile lifestyle to access different resources and engage in trade during the warmer months (Friesen 1999; Harritt 2013; Rainey 1947; Thornton 1931).

The increased addition of cooler-burning angiosperm taxa to F33-1 could have controlled heat output in the springtime. If the inhabitants of Feature 33 followed the traditional migration pattern, they would have lit their last fire in the spring. At any time of the year temperature control was important in these houses, which could become uncomfortably hot. When cooking, Iñupiat women needed to open their seal gut skylight to cool the interior, prevent ice in the sod superstructure from dripping, and to reduce carbon monoxide levels (Frink and Harry 2008:113). F33-1 was likely enclosed in a superstructure, and warming spring temperatures would heat up the interior too much. Adding cooler-burning firewood could have mitigated this problem by reducing heat output. Furthermore, burning less-energetic wood in warmer months could conserve hot-burning woody taxa for the winter.

If F68A-1 was a summertime pottery-firing feature, angiosperm wood might have functioned similarly to control temperature. During the summer, northwestern Alaska is cool and humid, which makes pottery production difficult. It is hard to dry clay pots before firing, and damp vessels explode when heat creates steam inside the body (Fink and Harry 2008:112). The solution is to use organic temper that makes ceramics highly porous and to fire wares at low temperatures. This prevents the clay from sintering while allowing steam to release (Fink and Harry 2008:112). Adding the correct ratio of different fuels may have kept firing temperatures suitably low.

Furthermore, the role of sea mammal oil must be considered. Thule people relied heavily on oil lamps for light, heat, and cooking. The living area in Feature 33 yielded an in situ oil lamp (Crawford 2012), and it appears that inhabitants may have intentionally added oil to F33-1, because the underlying surface is clinker. Furthermore, many charcoal fragments from both F68A-1 and F33-1 were permeated by a solid orange-brown substance, which appears to have been introduced as a liquid. I suspected that this was solidified sea mammal oil and sent a specimen for testing. Unfortunately, the test was inconclusive because the sample was too small to detect lipids beyond trace amounts (Crawford 2012:98).

If the substance was solidified oil, it could have originated from sea mammal oil, greasy bones, or fatty meat drippings. While the Iñupiat typically boiled their food, they did occasionally roast meat (Burch 2006), a practice that extends into antiquity. Alternatively, heated greasy bones release liquid fat into a fire and soak firewood. This added fat slows combustion and extends the life of the fire (Yravedra et al. 2017). De Laguna (1940) reported that the Iñupiat would soak firewood with seal oil when firing pots. If oil was added purposefully, it was to conserve fuel, control temperatures, extend burn times, and control combustion properties (e.g., flame height, the formation of cinders).

DID DRIFTWOOD DECLINE AT CAPE ESPENBERG?

The population at Cape Espenberg declined after AD 1700, but dwindling driftwood deposition was not a primary factor. Regionally, paleoclimatic reconstructions suggest that driftwood deposition was *higher* during the last 400 years or so (Alix 2012:96). Ethnohistorical accounts recall that there was plentiful driftwood into the nineteenth century before the introduction of the woodstove (Burch 2006:273). Both Feature 68A and Feature 33 were constructed out of heavy timbers rather than another material such as the bowhead whale bones that appear on the landscape. Both houses suggest there was enough fuel to ignore poplar, a fuel of last resort in ethnographic times. In sum, there is little evidence of driftwood decline and fuel scarcity during Thule times. Rather than fuel scarcity, the patterns seen at Feature 68A and Feature 33 represent fuel management strategies. The combination of bone, driftwood, twigs, and oil may be related to temperature control, seasonality, activity, and fuel conservation, not a shortage of driftwood.

Driftwood supplies eventually became insufficient to meet the demands of the local population. This may have been due to an actual decline of driftwood deposition, a perceived decline due to the large amounts of firewood needed to fuel woodstoves, or both. If driftwood deposition declined during the late precontact period, it does not appear to have been deleterious to the thinning late Thule population. Perhaps it was the combination of declining driftwood supplies and the introduction of the woodstove that is remembered in historical oral accounts.

CONCLUSION

This report contributes to our understanding of how Thule people selected firewood according to state- and taxon-specific combustion properties, how they managed fuel supplies, and how they controlled combustion properties by combining different fuels. Fuel use in the Far North is a complicated subject because bone, oil, and wood were used in varying amounts depending on cultural preferences, availability, activity, seasonality, and other variables. Until this subject is more fully understood, research will remain exploratory. There is little evidence of fuel shortages during Thule times. Instead, it was not until late precontact or postcontact times that driftwood supplies became insufficient.

ACKNOWLEDGEMENTS

I would like to thank the Iñupiaq people for insights and support, especially those students and Elders who volunteered at our site. This paper was developed from my 2012 master's thesis. My sincere thanks go to the many individuals who helped write and refine these results. I would especially like to thank John Darwent for providing many of the map figures for this article. Claire Alix and Owen Mason especially made significant contributions, and Nancy Bigelow, Ben Potter, Douglas Crews, Kris Gremillion, Mark Hubbe, and Brian Padgett all provided comments and advice. Andrew Meng graciously provided his statistical expertise. Furthermore, I owe a debt of gratitude to the participants of the 2010 and 2011 Cape Espenberg excavation who took hundreds of soil samples and assisted me with flotation. Financial support was provided by NSF project ARC-0755725 (PIs John Hoffecker and Owen Mason) and by a Chaire d'excellence CNRS/Paris 1 University awarded to Claire Alix.

REFERENCES

Alix, Claire

2001 *Exploitation du Bois par les Populations Néo-Eskimo entre le Nord de l'Alaska et le Haut Arctique Canadien* [Neo-Eskimo Wood Exploitation between Northern Alaska and the Canadian High Arctic]. Ph.D. dissertation, University Paris I–Panthéon Sorbonne, Paris.

2002 *Acquisition, transformation et circulation des ressources ligneuses dans l'Arctique nord-américain (culture de Thulé)* [Acquisition, transformation and circulation of woody resources in the North American Arctic (Thule Culture)]. Cross-Cutting Themes ArScAn II—*Archéologies et Sciences de l'Antiquité* 2000/2001:103–110, Nanterre.

2003 Wood Remains from the 2002 Excavation at Uivvaq, Cape Lisburne. In *Uivvaq Heritage Project Field Season 2002 Final Report*, edited by Owen K. Mason, pp. 193–199. Report to Aglaq/CONAM in fulfillment of contract 2103-004. GeoArch Alaska, Anchorage.

2004 *Bois Flotté et Archéologie de l'Arctique: Contribution à la Préhistoire Récente du détroit de Béring* [Driftwood and Arctic Archaeology: A Contribution to the Recent Prehistory of the Bering Strait]. *Études/Inuit/Studies* 28(1):109–131.

2005 Deciphering the Impact of Change on the Driftwood Cycle: Contribution to the Study of Human Use of Wood in the Arctic. *Global and Planetary Change* 47:83–98.

2008 *L'Usage du Bois en Alaska: Ethno-Archaeologie et Dendrochronologie* [Wood Use in Alaska: Ethnoarchaeology and Dendrochronology]. *Les Nouvelles de l'Archeologie* 111-112:45–50.

2009a Driftwood, Timber and Shrubs! Wood Used by Ruin Island Thule at Skraeling Island, Eastern Ellesmere Island, Canada. In *On the Track of the Thule Culture from Bering Strait to East Greenland*, edited by Bjarne Grønnow, pp. 149–165. The Proceedings of the SILA Conference "The Thule Culture—New Perspectives in Inuit Prehistory," Copenhagen, held 26–28 October 2006. SILVA–The Greenland Research Centre at the National Museum of Denmark. National Museum, Studies in Archaeology and History vol. 15.

2009b Persistence and Change in Thule Wood Use. In *The Northern World, AD 900–1400*, edited by Herbert Maschner, Owen K. Mason, and Robert McGhee, pp. 179–205. University of Utah Press, Salt Lake City.

2012 Using Wood on King Island, Alaska. *Études/Inuit/Studies* 36(1):89–112.

2016 A Critical Resource: Wood Use and Technology in the North American Arctic. In *The Oxford Handbook of the Prehistoric Arctic*, edited by T. Max Friesen and Owen K. Mason, pp. 109–130. Oxford University Press, New York.

Alix, Claire, and Karen Brewster

2004 Not All Driftwood is Created Equal: Wood Use and Value along the Yukon and Kuskokwim Rivers, Alaska. *Alaska Journal of Anthropology* 2(1):2–19.

Anagnost Susan E., Robert W. Meyer, and Carl de Zeeuw

1994 Confirmation and Significance of Bartholin's Method for the Identification of the Wood of *Picea* and *Larix. International Association of Wood Anatomists* 15(2):171–184.

Anderson, Douglas D.

1984 Prehistory of North Alaska. In *Handbook of North American Indians,* vol. 5*, Arctic*, edited by William C. Sturtevant and David Damas, pp. 80–93. Smithsonian, Washington DC.

Anderson, Douglas D., Wanni W. Anderson, Ray Bane, Richard K. Nelson, and Nita Sheldon Towarak

1988 *Kuuvaŋmiut Subsistence: Traditional Eskimo Life in the Latter Twentieth Century*. Department of the Interior, National Park Service, Washington, DC.

Arguez, Anthony, Imke Durre, Scott Applequist, Mike Squires, Russell Vose, Xungang Yin, and Rocky Bilotta

2010 NOAA's U.S. Climate Normals (1981-2010). NOAA National Centers for Environmental Information.

Bartholin, Thomas

1979 The *Picea-Larix* problem. *International Association of Wood Anatomists Bulletin* 1:7–10.

Benkova, Vera E., and Fritz Hans Schweingruber

2004 *Anatomy of Russian Woods: An Atlas for the Identification of Trees, Shrubs, Dwarf Shrubs and Woody Lianas from Russia*. Haupt Berne, Switzerland.

Beresford-Jones, David G., Katherine Johnson, Alexander G. Pullen, Alexander J.E. Pryor, Jirí Svoboda, and Martin K. Jones

2010 Burning Wood or Burning Bone? A Reconsideration of Flotation Evidence from Upper Paleolithic (Gravettian) sites in the Moravian Corridor. *Journal of Archaeological Science* 37:2799–2811.

Burch, Ernest S., Jr.

1998 *The Iñupiaq Eskimo Nations of Northwest Alaska*. University of Alaska Press, Fairbanks.

2006 *Social Life in Northwest Alaska: The Structure of Iñupiaq Eskimo Nations*. University of Alaska Press, Fairbanks.

Byrne, Chae, Emilie Dotte-Sarout, and Vicky Winton

2013 Charcoals as Indicators of Ancient Tree and Fuel Strategies. *Australian Archaeology* 77:94–106.

Collins, Henry B.

1937 *Archaeology of St. Lawrence Island, Alaska*. Smithsonian Miscellaneous Collections 81, Washington, DC.

Cook, John P.

1969 The Early Prehistory of Healy Lake, Alaska. Ph.D. dissertation, University of Wisconsin.

Crawford, Laura J.

2012 Thule Plant and Driftwood Use at Cape Espenberg, Alaska. Master's thesis, University of Alaska, Fairbanks.

Darwent, John, John F. Hoffecker, and Christyann M. Darwent

2013 1,000 Years of House Change at Cape Espenberg, Alaska: A Case Study in Horizontal Stratigraphy. *American Antiquity* 78(3):433–455.

de Laguna, Frederica

1940 Eskimo Lamps and Pots. *Journal of the Royal Anthropological Institute of Great Britain and Ireland* 70(1):53–76.

Deo-Shaw, Jennie

2008 Driftwood as a Resource*:* Modeling Fuelwood Acquisition Strategies in the Mid- to Late Holocene Gulf of Alaska. Ph.D. dissertation, University of Washington, Seattle.

2012 Economies of Driftwood: Fuel Harvesting Strategies in the Kodiak Archipelago. *Études/Inuit/Studies* 36(1):63–88.

Dufraisse, Alexa
2006 Firewood Economy During the Fourth Millennium BC at Lake Clairvaux, Jura, France. *Environmental Archaeology* 11(1):87–99.

Dufraisse, Alexa, and María Soledad García Martínez
2011 Measurer les Diamètres du Bois de Feu en Anthracologie. Outils Dendrométriques et Interprétation des Données [Interpreting Data from Anthracological Firewood Diameter Measurements Taken with Dendrometric Tools]. *Anthropobotanica* 2:1–18.

Dyke, Arthur S., John England, Erk Reimnitz, and Hélène Jetté
1997 Changes in Driftwood Delivery to the Canadian Arctic Archipelago: The Hypothesis of Postglacial Oscillations of the Transpolar Drift. *Arctic* 50(1):1–16.

Ford, James A.
1959 *Eskimo Prehistory in the Vicinity of Point Barrow, Alaska*. Anthropological Papers of the American Museum of Natural History no. 47, New York.

Friesen, T. Max
1999 Resource Structure, Scalar Stress, and the Development of Inuit Social Organization. *World Archaeology* 31(1):21–37.

Friesen, T. Max, and Matthew W. Betts
2006 Archaeofaunas and Architecture: Zooarchaeological Variability in an Inuit Semi-Subterranean House, Arctic Canada. In *Integrating Zooarchaeology*, edited by Mark Maltby, pp. 64–75. Oxbow Books, Oxford.

Frink, Lisa, and Karen G. Harry
2008 The Beauty of "Ugly" Eskimo Cooking Pots. *American Antiquity* 73(1):103–120.

Giddings, James Louis, Jr.
1941 Dendrochronology in Northern Alaska. *University of Arizona Bulletin* 12(4).
1952a *The Arctic Woodland Culture of the Kobuk River*. University Museum, University of Pennsylvania, Philadelphia.
1952b Driftwood and Problems of Arctic Sea Currents. *Proceedings of the American Philosophical Society* 96(2):129–142.

Giddings, James Louis, Jr., and Douglas D. Anderson
1986 *Beach Ridge Archaeology of Cape Krusenstern*. Department of the Interior, National Park Service, Washington, DC.

Harritt, Roger K.
1994 *Eskimo Prehistory of the Seward Peninsula, Alaska*. Department of the Interior, National Park Service, Alaska Regional Office.
1995 The Development and Spread of the Whale Hunting Complex in Bering Strait: Retrospect and Prospects. In *Hunting the Largest Animals: Native Whaling in the Western Arctic and Subarctic*, edited by Allen P. McCartney, pp. 33–45. Canadian Circumpolar Institute, University of Alberta, Edmonton.
2013 Toward an Archaeology of Late Prehistoric Eskimo Bands in Coastal Northwest Alaska. *Journal of Anthropological Archaeology* 32:659–674.

Harry, Karen, and Liam Frink
2009 The Arctic Cooking Pot: Why Was It Adopted? *American Anthropologist* 111(3):330–343.

Heinz, Christine, and Stéphanie Thiébault
1998 Characterization and Palaeoecological Significance of Archaeological Charcoal Assemblages during Late and Post-Glacial Phases in Southern France. *Quaternary Research* 50:56–58.

Higuera, Philip E., Linda B. Brubaker, Patricia M. Anderson, Feng Sheng Hu, and Thomas A. Brown
2009 Vegetation Mediated the Impacts of Postglacial Climate Change on the Fire Regimes in the South-Central Brooks Range, Alaska. *Ecological Monographs* 79(2):201–219.

Hoadley, Bruce R.
1990 *Identifying Wood: Accurate Results with Simple Tools*. Taunton Press, Newtown, CT.

Hoffecker, John F.
2005 Innovation and Technological Knowledge in the Upper Paleolithic of Northern Eurasia. *Evolutionary Anthropology* 14:186–198.

Hoffecker, John F., and Owen K. Mason
2010 *Human Response to Climate Change at Cape Espenberg AD 800–1400: Field Investigations at Cape Espenberg, 2010.* Annual Report to the National Park Service, U.S. Department of the Interior. Institute of Arctic and Alpine Research, University of Colorado, Boulder.
2011 *Human Response to Climate Change at Cape Espenberg AD 800–1400: Field Investigations at Cape Espenberg, 2011.* Annual Report to the National Park Service, U.S. Department of the Interior. Institute of Arctic and Alpine Research, University of Colorado, Boulder.

Hole, Georgia M., and Marc Marcias-Fauria
2017 Out of the Woods: Driftwood Insights into Holocene Pan-Arctic Sea Ice Dynamics. *Journal of Geophysical Research: Oceans* 122:7612–7629.

Jones, Anore
2010 *Plants that We Eat: Nauriat Nigiñaqtuat: From the Traditional Wisdom of the Iñupiat Elders of Northwest Alaska*. University of Alaska Press, Fairbanks.

Larsen, Helge
2001 *Deering—A Men's House from Seward Peninsula, Alaska.* Greenland Research Centre, Copenhagen, Denmark.

Larsen, Helge, and Froelich Rainey
1948 Ipiutak and the Arctic Whale Hunting Culture. *Anthropological Papers of the American Museum of Natural History* 42:1–67.

Lee, Molly and Gregory Reinhardt
2003 *Eskimo Architecture: Dwelling and Structure in the Early Historic Period*. University of Alaska Press, Fairbanks.

Leslie, Lynn D.
1986 *Alaska Climate Summaries*. Alaska Climate Center Technical Note no. 3, Arctic Environmental Information and Data Center, University of Alaska, Anchorage.

Marguerie, Dominique, and Jean-Yves Hunot
2007 Charcoal Analysis and Dendrology: Data from Archaeological Sites in North-Western France. *Journal of Archaeological Science* 34:1417–1433.

Marquer, Laurent, Vincent Lebreton, Thierry Otto, H. Valladas, P. Haesaerts, Erwan Messager, D. Nuzhnyi, and Stéphane Péan
2012 Charcoal Scarcity in Epigravettian Settlements with Mammoth Bone Dwelling: The Taphonomic Evidence from Mezhyrich (Ukraine). *Journal of Archaeological Science* 39:109–120.

Marquer, Laurent, Thierry Otto, Roland Nespoulet, and Laurent Chiotti
2010 A New Approach to Study the Fuel Used in Hearths by Hunter-Gatherers at the Upper Paleolithic Site of Abri Pataud (Dordogne, France). *Journal of Archaeological Science* 37:2735–2746.

Mason, Owen K.
1990 Beach Ridge Geomorphology of Kotzebue Sound: Implications for Paleoclimatology and Archaeology. Ph.D. dissertation, Department of Anthropology, University of Alaska Fairbanks.
1998 The Contest Between the Ipiutak, Old Bering Sea, and Birnirk Polities and the Origin of Whaling During the First Millennium AD Along Bering Strait. *Journal of Anthropological Archaeology* 17:240–325.
2013 Ipiutak Remains Mysterious: A Focal Place Still Out of Focus. In *Dynamics of Northern Societies*, edited by Jette Arneborg and Bjarne Grønnow, pp. 103–119. Publications from the National Museums, Copenhagen.
2016 Thule Origins in the Old Bering Sea Culture: the Inter-relationship of Punuk and Birnirk Cultures. In *Oxford Handbook of the Prehistoric Arctic*, edited by T. M. Friesen and O. K. Mason, pp. 489–512. Oxford University Press, Oxford.

Mason, Owen K., and James E. Begét
1991 Late Holocene Flood History of the Tanana River, Alaska, U.S.A. *Arctic and Alpine Research* 23(4):392–403.

Mason, O. K., and P. M. Bowers
2009 The Origin of Thule is Always Elsewhere: Early Thule within Kotzebue Sound, Cul-de-Sac or Nursery? In *On the Track of the Thule Culture from Bering Strait to East Greenland,* edited by B. Grønnow, pp. 25–44. Aarhus University Press, Aarhus.

Mason, Owen K., and S. Craig Gerlach
1995 Chukchi Hot Spots, Paleo-Polynyas, and Caribou Crashes: Climatic and Ecological Dimensions of North Alaska Prehistory. *Arctic Anthropology* 32(1):101–130.

Mason, Owen K., John F. Hoffecker, Nancy H. Bigelow, and John Darwent
2008 *Final Report to the National Park Service: The Thule Origins and Climate Change at Cape Espenberg SGER-NSF Survey, 2007.* Cape Espenberg Archaeological Mapping and Paleoecological Assessment, Institute of Arctic and Alpine Research, University of Colorado, Boulder.

Mason, Owen K., David M. Hopkins, and Lawrence Plug
1997 Chronology and Paleoclimate of Storm-Induced Erosion and Episodic Dune Growth Across Cape Espenberg Spit, Alaska, U.S.A. *Journal of Coastal Research* 13(3):770–797.

Mason, Owen K., and James W. Jordan
1993 Heightened North Pacific Storminess During Synchronous Late Holocene Erosion of Northwest Alaska Beach Ridges. *Quaternary Research* 40(1):55–69.

Mathiassen, Therkel
1927 Archeology of the Central Eskimos. Report of The Fifth Thule Expedition, 1921–1924. The Danish Expeditions to Arctic North America in Charge of Knud Rasmussen, Ph.D. dissertation, vol. 4(1–2). Gyldendalske Boghandel, Nordisk Forlag, Copenhagen.

McIntosh, Stacie J.
1999 *Nuasiaq* = Plant?: Ethnobotanical Classification in Shishmaref, Alaska. Master's thesis, Department of Anthropology, University of Alaska Fairbanks.

McCullough, Karen M.
1989 *The Ruin Islanders: Thule Culture Pioneers in the Eastern High Arctic*. Hull, Canadian Museum of Civilization Mercury Series 141, Canadian Museum of Civilization.

Méreuze, Rémi
2015 La Construction de la Maison 33 du Cap Espenberg, Nord-Ouest de l'Alaska, au Xviii[e] Siècle [The Construction of 18th Century House Feature-33 at Cape Espenberg, Northwestern Alaska]. *Les Nouvelles de L'Archéologie* 141:1–11.

Mooney, Dawn Elise
2013 The Use and Control of Wood Resources in Viking Age and Medieval Iceland. Ph.D. dissertation, Department of Archaeology, University of Aberdeen, Aberdeen.

Osgood, Cornelius
1958 *Ingalik Social Culture*. Yale University Publications in Anthropology 16. Yale University Press, New Haven.

Panshin, Alexis John, and Carl de Zeeuw
1980 *Textbook of Wood Technology: Structure, Identification and Uses of the Commercial Woods of the United States and Canada*. 4th ed. McGraw-Hill Book Company, New York.

Pearsall, Deborah
2015 *Paleoethnobotany, Third Edition: A Handbook of Procedures*. Left Coast Press, Walnut Creek, CA.

Rainey, Froelich
1947 *The Whale Hunters of Tigara*. Anthropological Papers of the American Museum of Natural History 41(2):231–283.

Saario, Doris J., and Brina Kessel
1966 Human Ecological Investigations at Kivalina. In *Environment of the Cape Thompson Region, Alaska*, edited by John Nicholas Wolfe and Norman H. Wilimovsky, United States Atomic Energy Commission Division, Division of Technical Information, University of Alaska Fairbanks.

Schaaf, Jeanne M.
1996 Before Our Fathers' Time: Late Prehistoric Inupiat of the Northern Seward Peninsula. In *Ublasaun/First Light: Inupiaq Hunters and Herders in the Early Twentieth Century, Northern Seward Peninsula, Alaska*, pp. 42–61. Shared Beringian Heritage Program, National Park Service, Anchorage.

Schaaf, Jeanne M., David M. Hopkins, James W. Jordan, Owen K. Mason, and Dale M. Vinson
1988 *The Bering Land Bridge National Preserve: An Archaeological Survey*. National Park Service, Alaska Regional Office.

Sheehan, Glenn W.
1995 Whaling Surplus, Trade, War, and the Integration of Prehistoric Northern and Northwestern Alaskan Economies, AD 1200–1286. In *Hunting the Largest Animals: Native Whaling in the Western Arctic and Subarctic*, edited by Allen P. McCartney, pp. 185–206. Canadian Circumpolar Institute, University of Alberta.
1997 *In the Belly of the Whale: Trade and War in Eskimo Society*. Alaska Anthropological Association Series VI, Anchorage.

Shelton, China P., and Chantel E. White
2010 The Hand-Pump Flotation System: A New Method for Archaeobotanical Recovery. *Journal of Field Archaeology* 35(3):316–326.

Taylor, William E., Jr.
1963 Hypotheses on the Origin of Canadian Thule Culture. *American Antiquity* 28(4):456–464.

Théry-Parisot, Isabelle
2002 Fuel Management (Bone and Wood) During the Lower Aurignacian in the Pataud Rock Shelter (Lower Palaeolithic, Les Eyzies de Tayac, Dordogne, France). Contribution of Experimentation. *Journal of Archaeological Science* 29:1415–1421.

Théry-Parisot, Isabelle, Lucie Chabal, and Julia Chrzavzez
2010 Anthracology and Taphonomy from Wood Gathering to Charcoal Analysis: A Review of the Taphonomic Processes Modifying Charcoal Assemblages in Archaeological Contexts. *Paleogeography, Palaeoclimatology, Palaeoecology* 291:142–153.

Thornton, Harrison Robertson
1931 *Among the Eskimos of Wales, Alaska, 1890–93*. Johns Hopkins Press, Baltimore.

Tremblay, Bruno L., Lawrence A. Mysak, and Arthur S. Dyke
1997 Evidence from Driftwood Records for Century-to-Millennial Scale Variations of the High Latitude Atmospheric Circulation during the Holocene. *Geophysical Research Letters* 24(16):2027–2030.

Tremayne, Andrew
2015 New Evidence for the Timing of Arctic Small Tool Tradition Coastal Settlement in Northwest Alaska. *Alaska Journal of Anthropology* 13(1):1–18.

Vanlandeghem, Marine, Claire Alix, Michelle Elliott, and Isabelle Théry-Parisot
2015 Thule Fuel Management at Cape Espenberg (N-W Alaska): Experimental Protocol and Data Set from Current Driftwood Deposits and Archaeological Charcoal Remains. Paper presented at 6th International Anthracology Meeting, Freiberg, Germany, 30 August–4 September 2015.

Walker, Glenn, and Jack Shostak
2010 *Common Statistical Methods for Clinical Research With SAS Examples: Third Edition*. SAS Institute, Cary, NC.

Webster, Donald H., and Wilfried Zibell
1970 *Iñupiat Eskimo Dictionary*. Alaska Rural School Project, Department of Education, University of Alaska, College, AK.

Wheeler, Robert, and Claire Alix
2004 *Economic and Cultural Significance of Driftwood in Coastal Communities of Southwest Alaska*. Report to the Cooperative Extension Service, University of Alaska Fairbanks.

Whitridge, Peter James
1999 The Construction of Social Difference in a Prehistoric Inuit Whaling Community. Ph.D. dissertation, Department of Anthropology, Arizona State University, Tempe.

Yravedra, José, David Álvarez-Alonso, Verónica Estaca-Gómez, Pablo López-Cisneros, Álvaro Arrizabalaga, Mikelo Elorza, Ma. José Iriarte, Jesús F. Jordá Pardo, Carmen Seśe, and Paloma Uzquiano
2017 New Evidence of Bones Used as Fuel in the Gravettian at Coímbre Cave, Northern Iberian Peninsula. *Archaeological and Anthropological Sciences* 9:1153–1168.