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A Thousand Years of Lost Hunting Arrows: Wood Analysis of Ice Patch Remains in Northwestern Canada

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ABSTRACT. Discussions of the development of past hunting equipment generally focus on lithic and bone projectile points and foreshafts, as these are often the only elements remaining in archaeological sites. In the last 15 years, the archaeology of alpine ice patches has provided a unique opportunity to analyze hunting equipment over time and gain knowledge of the wooden elements on which the points are hafted. This paper describes the wood and morphometrical analysis of a collection of 27 arrow shafts from two ice patch regions of the western Canadian Subarctic. In both regions, two main categories of arrow shafts show the selection of specific pieces of wood, spruce (*Picea* sp.) on the one hand and birch (*Betula* sp.) on the other, with associated morphometrical characteristics. These shafts also share some characteristics that are distinct from those of Arctic and coastal arrow shafts. Shafts of pine (*Pinus* sp. sec. *ponderosa*) and hemlock (*Tsuga* sp.) were also identified in the southwestern Yukon Territory. The absence of correlation between the arrow shaft types and ^{14}C dating raises the question of the significance of the arrow types and the potential for function, trade, or travel to explain the variation.

Key words: archery, arrow shafts, ice patch archaeology, wood analysis, xylology, Subarctic, Arctic, Southwest Yukon, Northwest Territories

RÉSUMÉ. Les discussions sur le développement des armes de chasse se concentrent généralement sur les pointes de projectile et les préhampes en matières lithiques et osseuses car ce sont ces éléments qui sont les plus souvent retrouvés dans les sites archéologiques. Ces quinze dernières années, l'archéologie des névés alpins nous donne l'opportunité unique d'analyser des équipements de chasse sur le long terme et de documenter les éléments en bois au bout desquels les pointes sont emmanchées. Dans cet article, nous décrivons l'analyse d'une collection de vingt-sept hampes de flèche en bois végétal provenant de deux régions de névés du Subarctique canadien. Dans les deux régions, on définit deux catégories principales de hampes de flèche qui montrent une sélection spécifique de pièces de bois d'épicéa (*Picea* sp.) et de bouleau (*Betula* sp.) auxquelles correspondent des caractéristiques morphométriques propres. Ces hampes partagent aussi des caractéristiques qui les distinguent de celles plus nordiques des côtes de l'Arctique. Des hampes faites en bois de pin (*Pinus* sp. sec. *ponderosa*) et de pruche (*Tsuga* sp.) ont également été identifiées dans le Sud-ouest du Territoire du Yukon. L'absence de corrélation entre les types de hampe de flèche et les dates radiocarbone soulève la question du sens à donner à ces types de flèche. Des facteurs tels que la fonction, les échanges ou des déplacements de personne sont envisagés.

Mots clés : archerie, hampe de flèche, archéologie des névés, analyse des bois, xylologie, Subarctique, Arctique, Sud-ouest du Yukon, Territoires du Nord-Ouest

INTRODUCTION

The study of archery and the debate over the timing of the transition from atlatl and dart to bow and arrow, in both the Old World and the New World, are most often seen through analyses of dart and arrow projectile points. Indeed, the point is often the only element of these composite weapons to be left in archaeological sites. As a result of this lack of preservation, archaeologists often forget that wood mattered in the making of the arrow and that not just any feathers were used (e.g., Dove et al., 2005; Andrews et al., 2012a). Moreover, wood, although mostly seen as used for the shaft, was often a legitimate material for the foreshaft or even the end point of an arrow, or both (Waguespack et al., 2009). The ethnographic record gives ample evidence of such usages (e.g., Turner, 1998), and the discoveries made from melting ice patches over the past 15 years show the importance of wood in the making of foreshafts used for large mammal hunting (Hare et al., 2004, 2012; Dixon et al., 2005; Andrews et al., 2012a, b) although the northern boreal forest is not particularly celebrated for having strong and tough wood. In the "everyday" archaeological record,

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TABLE 1. Wood reported by early ethnographers as being used for arrow making among the First Nations of British Columbia, Yukon Territory, and interior Alaska. Species in bold are identified in the present study.

		Species						
Region	First Nation Group	***Betula* sp. (birch)**[1]	***Picea* sp. (spruce)**[2]	*Amelanchier alnifolia* (Saskatoon berry)[3]	***Pinus contorta* (lodgepole pine)**	*Acer* sp. (maple)	*Thuya plicata* (red cedar)[4]	References
British Columbia	Salish (Interior & Coast)			x				Turner, 1998
	Dunmeza	x						Turner, 1998
	Carrier			x				Turner, 1998
	Gitksan			x		x		Smith, 1997; Turner, 1998
	Ktunaxa			x				Turner, 1998
	Lower Nlaka'pamux					x		Turner, 1998
	Lower Stl'al'imx					x		Turner, 1998
	Tahtlan				x[5]			Turner, 1998
	Upper Sto:lo			x				Turner, 1998
Interior Alaska and Yukon Territory	Kutchin/Gwitch'in		x	x				Osgood, 1936; Alix, 2008b
	Slavey			x				Williamson, 1955
	Upper Tanana		x					McKennan, 1959
	Han	x	x					Schmitter, 1910; Osgood, 1971
	Deg Hit'an		x					Osgood, 1940
South-central Alaska	Denai'na	x	x				x	Osgood,1937; Russel Kari, 1995

[1] *Betula* sp., most probably Alaska paper birch, *Betula neoalaskana* or *Betula papyrifera*.

[2] *Picea* sp., most probably white or black spruce (*Picea glauca* and *Picea mariana*) and possibly *Picea sitchensis*.

[3] Thin, straight branches of Saskatoon berry, often fire-hardened: "the branches were the chief wood for arrows as they were strong" (Smith, 1997:110).

[4] Red cedar from southeastern Alaska found as driftwood.

[5] The wood of lodgepole pine is only occasionally used.

evidence of wood used in arrows is rarer, though there are exceptions, such as the Ozette site on the Washington state coast, discovered and excavated in the 1970s (Friedman, 1975; Gleeson, 1980). There, over half of the functioning arrowheads were made of wood, and to be more specific, of spruce compression wood, probably Sitka spruce (*Picea* sp. cf. *P. sitchensis* (Bong.) Carr.) (Friedman, 1975:125–130). Curiously, such facts are rarely mentioned or considered in the literature dealing with the evolution of dart and arrow hunting technology. The question of the efficiency of arrow points for large mammal hunting is considered, and stone is compared and opposed to antler (Ellis, 1997). However, statements such as the following, reported for Native groups like the Gitksan of the Northwest coast of North America, are rarely commented upon or taken into account:

> The wood [of nootka rose (*Rosa acicularis* Lindl.)], being hard and light, after it was dried, was used for arrow points for shooting bears and men. The arrow was pulled out of the wound, leaving the point in it. *Such arrows points would go straight because the points were not heavy. Stone was never used for arrow points.* (Smith, 1997:121, emphasis added)

In experimental work or statistical analyses aimed at providing insight into the debate on arrows vs. darts, or stone vs. bone material, the specific characteristics of the shaft—and particularly those of the wood used for the shaft—are rarely considered as potential variables. At the same time, while many of the earliest arrow shafts found in the Old World, such as the pine arrow shafts from Stellmoor (Cattelain, 2006:49), are made on split staves of wood, many archaeological experiments use sapling, straightened branches, or premade store-bought shafts and focus primarily on the hafting and the point. Yet any archery manual will explain how important the shaft is in the making and the flight of an arrow, and a quick survey of early ethnographic literature of the western Subarctic and Northwest coast (Table 1) shows that wood types and characteristics are almost always specified, as well as the morphology and dimensions of the shafts.

For the last 15 years, complete or nearly complete darts, arrows, and bow fragments in remarkable states of preservation have been found in the alpine regions of Subarctic Canada, in the southern Yukon and western Northwest Territories (Fig. 1). These wooden weapon elements and their associated antler or stone projectiles and feathers span 8000 years and 3000 years of hunting activities, respectively, in these two alpine environments (Hare et al., 2004, 2012; Andrews et al., 2012a, b). They are testimony to the importance of these remote areas for summer hunting activities and offer a unique opportunity to analyze hunting implements that were in use when they ended up lost or abandoned. Because they were found in ice patches where caribou dung is prominent and where caribou bones dominate associated faunal assemblages, it is safe to assume that

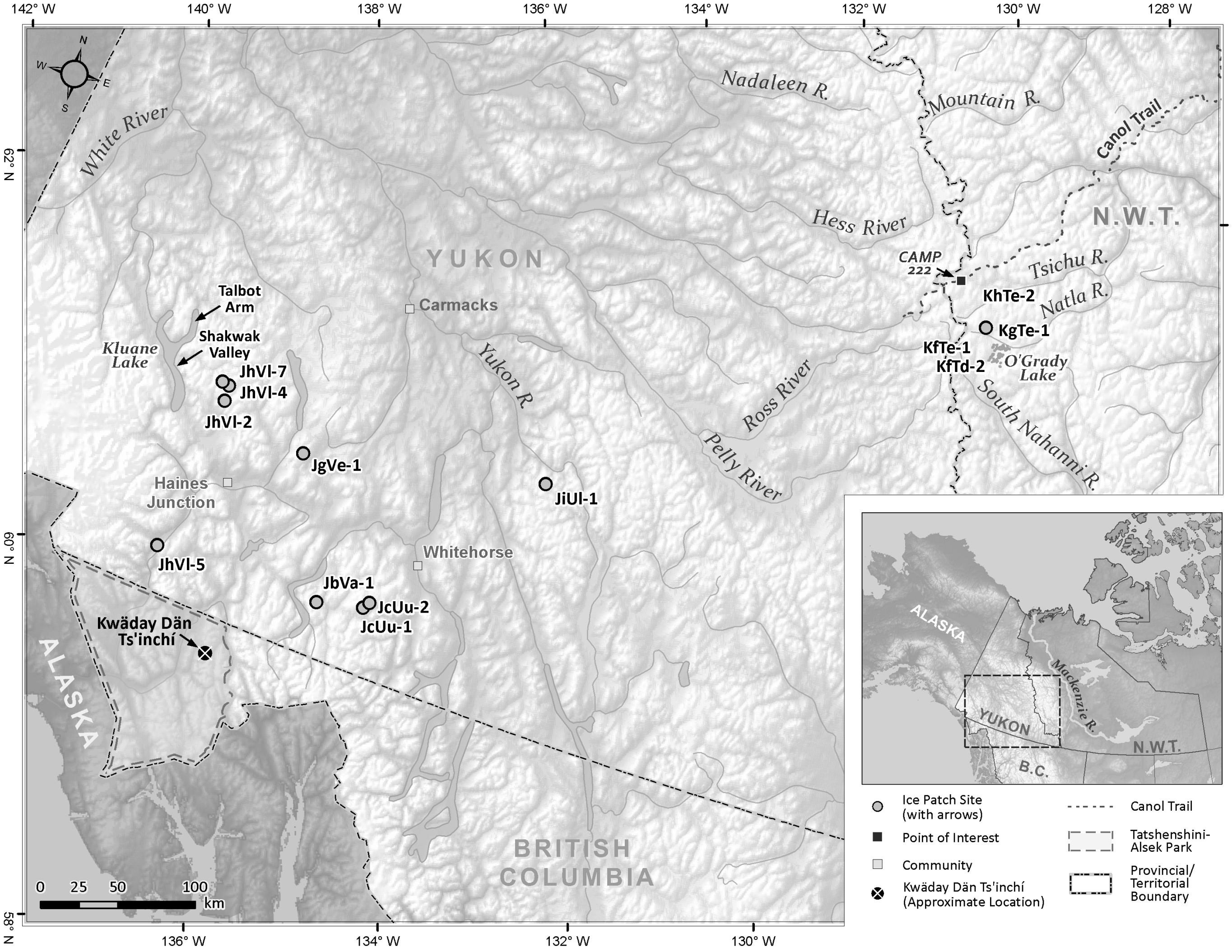

FIG. 1. Location of ice patches with arrow shaft finds and other locations mentioned in the text (map by Amy Barker).

these arrows were used mainly for summer caribou hunting even if other large and small terrestrial mammals (i.e., mountain sheep, ground squirrel, and marmot) were hunted as well (see Andrews et al., 2012b; Hare et al., 2012).

These mostly complete shafts for darts and arrows correspond to hunting events during which the hunter missed his prey and lost his dart or arrow. The bows, on the other hand, were probably left behind following their failure. Lost or left in the snow, these organic objects provide a remarkable insight into the Subarctic past.

Wood analysis of these artifacts from the southwestern Yukon shows that the wood was carefully selected and that the selection changed over time, from willow to birch wood for dart shafts to mainly spruce for arrow shafts (Hare et al., 2004). Some taxa identified were not necessarily abundant in the vicinity of these alpine hunting grounds and raised questions about mobility, trade, and exchange, and possibly about the use of these alpine areas by various hunters or groups of hunters. In this paper, we discuss the nature and adequacy of the wood used for making arrow shafts in Subarctic northwestern Canada.

MATERIAL AND METHOD

We report on the analysis of 27 arrow shafts (Table 2, Figs. 2 and 3) from the Coast Mountains of southwestern Yukon and the Selwyn Mountains of the Northwest Territories (Fig. 1). In southwestern Yukon, a series of ice patches located within or near the territories of the Ta'an Kwäch'än Council, Teslin Tlingit Council, and Carcross-Tagish, Champagne and Aishihik, Kluane, and Kwanlin Dün First Nations has provided the largest collection of arrow shafts and their associated heads and feathers, with a total of 24 complete and fragmented shafts and at least 15 arrow points. In the Northwest Territories, several ice patches located within the Tulita region of the Sahtu Dene First Nation have revealed four complete or fragmented arrow shafts, several stone arrow points, lashing sinew, and feathers (Table 2).

All but three arrow shafts are complete or nearly complete; 23 have a preserved distal end and 18 a preserved proximal (or nock) end, and only 2 are middle shaft fragments. Just over half of the arrow shafts have either lashing

TABLE 2. Information on the arrow shafts described in the text.

Artifact #	Frag.[1]	Wood taxon	Length (cm)	Nock type or Prox. end[4]	Fletching type	Distal end	Associated arrowhead type	Laboratory #	Conventional age ^{14}C yr BP	Calibrated age ranges (2σ range)	Median calibrated age (cal. yr BP ± 95% CI)
Coast Mountains Ice Patches, Southwest Yukon:											
JhVl-7:1	C	*Picea* sp.	72	U	None	Closed socket	–	Beta-197688	760 ± 40	650–770	700 ± 60
JhVl-7:2	LP	*Picea* sp.	58	Ψ	Lashing marks	–	–	Beta-274209	660 ± 40	550–680	610 ± 65
JhVl-4:3	LD	*Picea* sp.	57	–	None	Open socket	Antler	Beta-224136	150 ± 40	0–290	150 ± 145
JhVl-4:8	C	*Picea* sp.	61.5	V	Lashing marks	Open socket	Antler	Beta-224142	290 ± 40	150–470	380 ± 160
JhVl-2:1	C	*Picea* sp.	56	Ψ	None	Closed socket	Antler	Beta-172878	670 ± 40	550–690	630 ± 70
JhVl-5:1	LD	*Picea* sp.	60.5	–	None	Closed socket	–	Beta-224145	880 ± 40	720–920	790 ± 100
JgVe-1:6	LM	*Betula* sp.[2]	51.5	–	–	–	–	Beta-212886	430 ± 40	540–320	490 ± 120
JgVe-1:2	C	*Picea* sp.	58	U	Lashing marks	Closed socket	Antler	Beta-137729	680 ± 40	550–680	610 ± 65
JbVa-1:5	C	*Picea* sp.	56	U	None	Closed socket	–	Beta-37726	400 ± 40	310–520	460 ± 105
JbVa-1:1	C	*Picea* sp.	67.7	V	Lashing marks	Closed socket	–	Beta-137725	440 ± 40	310–550	490 ± 120
JbVa-1:13	LD	*Betula* sp.[2]	43.8	bevel	–	Split	–	Beta-274206	860 ± 40	680–910	770 ± 115
JbVa-1:3	C	*Pinus* sp.[3]	62.5	Ψ	None	Closed socket	Antler	Beta-137726	1010 ± 40	790–1050	930 ± 130
JcUu-1:8	SD	*Picea* sp.	24	–	–	Closed socket	–	Not dated			
JcUu-1:1	LP	*Betula* sp.[2]	100	U	–	–	–	Beta-13641 Beta-140625	3510 ± 70 3600 ± 40	3610–3980 3730–4080	3790 ± 185 3910 ± 175
JcUu-2:7	C	*Picea* sp.	52.2	U	Lashing marks	Closed socket	Bone	Beta 140625	90 ± 40	10–270	130 ± 130
JcUu-2:16	C	*Picea* sp.	58.9	U	3 feathers	Closed socket	Antler	Beta-152445	190 ± 40	0–310	180 ± 155
JcUu-2:19	C	*Picea* sp.	53.5	U	3 feathers	Closed socket	–	Beta-274210	250 ± 40	0–440	300 ± 200
JcUu-2:28	LM	*Picea* sp.	57.4	–	–	–	–	Beta-227524	340 ± 40	300–490	390 ± 95
JcUu-2:17	C	*Tsuga* sp.	73.11	Ψ	Sinew lashing	Split	Antler	Beta-212892	360 ± 40	310–510	410 ± 100
JcUu-2:26	C	*Betula* sp.[2]	101	U	None	Split	–	Beta-197686	620 ± 40	540–670	600 ± 65
JcUu-2:25	LD	*Betula* sp.[2]	74.5	U	Lashing marks	Bevel	–	Beta-224140	700 ± 40	550–710	660 ± 80
JcUu-2:5/ JcUu-1:3[5]	C	*Picea* sp.	62	Ψ	Lashing marks	Closed socket	–	Beta-140628 Beta-126342	810 ± 40 810 ± 40	670–800	720 ± 65
JiUl-1:2	C	*Betula* sp.[2]	72.5	U	None	Split	–	Wk-28993 Beta-274207	807 ± 30 1720 ± 40	670–780 1720–1530	720 ± 55 1630 ± 95
Selwyn Mountains, Northwest Territories:											
KgTe-1:1-5	LD	*Betula* sp.[2]	79.29	–	None	Split	Chert, notched	Beta -240096	270 ± 40	0–464	230 ± 230
KhTe-2:1-6	C	*Betula* sp.[2]	85.8	Ψ	3 feathers	Split	Chert, notched	Beta-240097	340 ± 40	308–488	400 ± 90
KfTd-2:1	SD	*Betula* sp.[2]	20.9	bevel	–	Split	–	Beta-256285	570 ± 40	521–650	590 ± 70
KfTe-1:11	SD	*Picea* sp.	25.8	–	–	Closed socket	–	Beta-256287	850 ± 40	684–904	790 ± 110

[1] Type of fragment: C: complete, LD: Long distal, LP: Long Proximal; SD: short distal; LM: Long medial.

[2] *Betula* sp. cf. *B. neoalaskana*.

[3] *Pinus* sp. cf. *P. contorta*.

[4] Ψ represents the open U notch after Mason, 1894:664 “U shape cut with […] gracefully curved incisions resembling the horizontal portion of the Greek letter psi.”

[5] One arrow is a perfect refit of two shaft fragments found in nearby but distinct ice patches, JcUu-1 and JcUu-2. A field reporting error or a broken arrow transported by a speared caribou that fell shortly afterwards could explain why these fragments were found so far from each other, but the true cause remains an enigma.

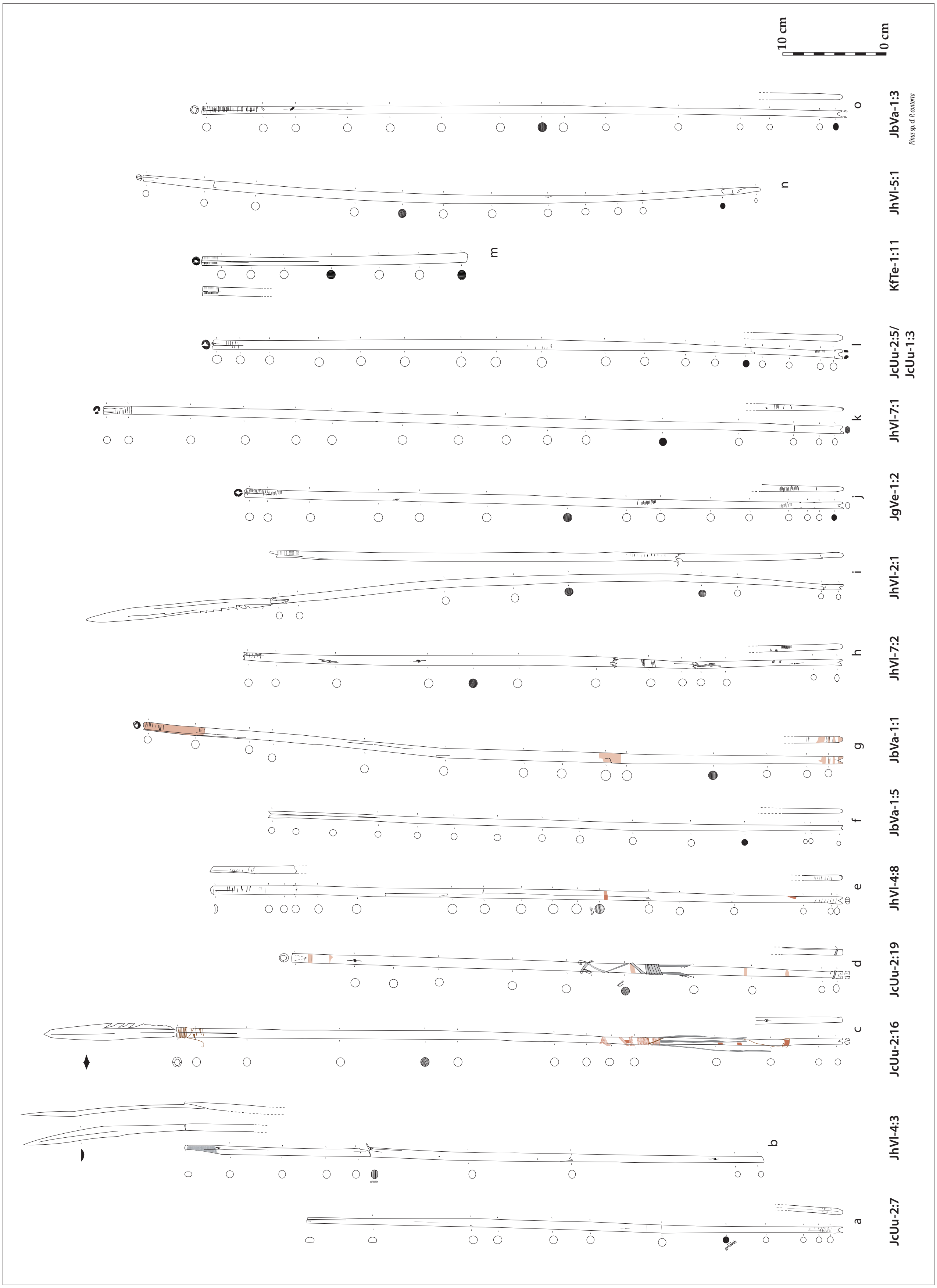

FIG. 2. Fifteen of the spruce and pine arrow shafts from the Coast Mountains and the Selwyn Mountains ice patches (chronologically ordered, youngest at left). (Drawings by C. Alix.)

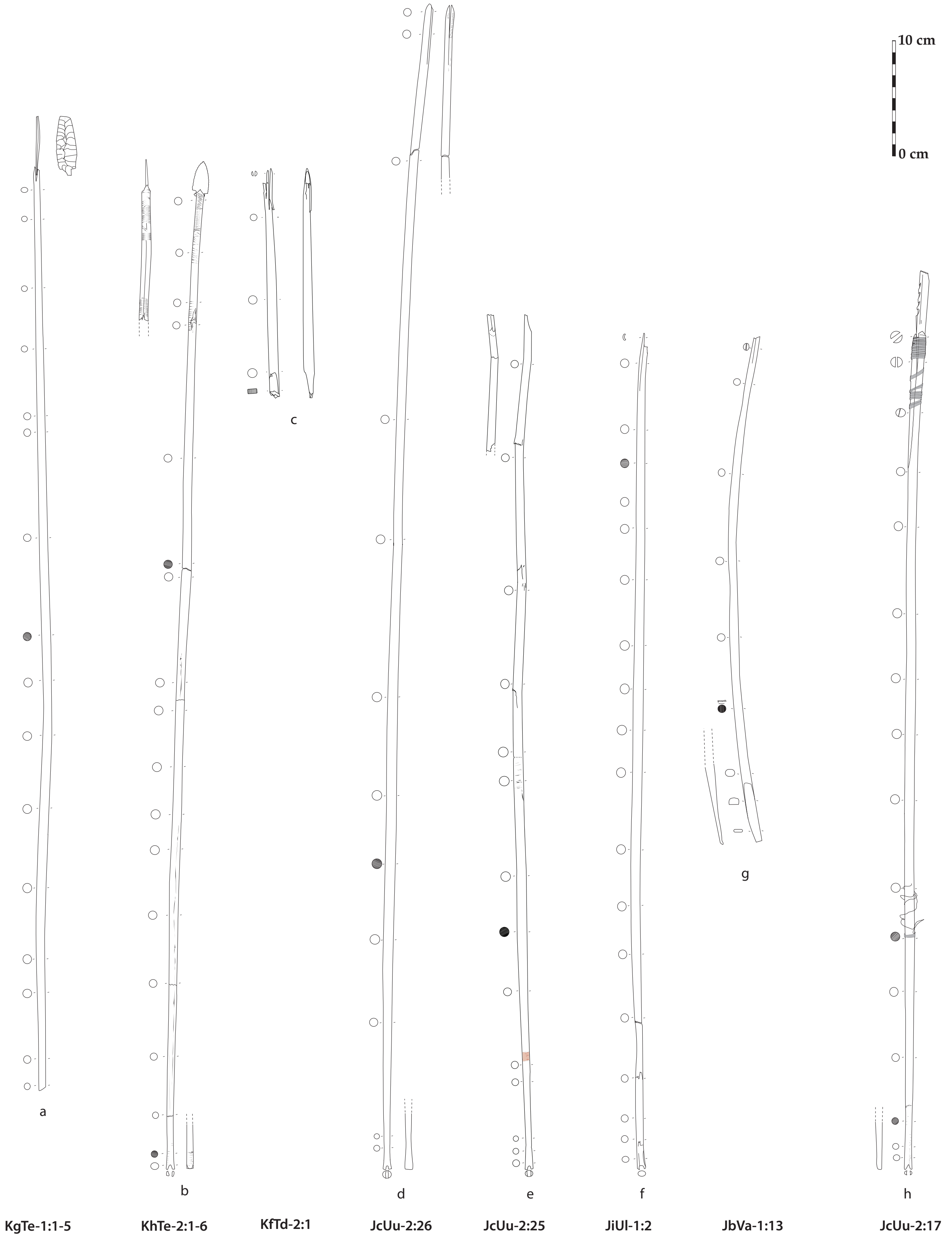

FIG. 3. Seven of the birch arrow shafts and one hemlock arrow shaft (JcUu-2:17) from the two ice patch regions. The birch arrow shafts are in chronological order, with the youngest at the left. (Drawings by C. Alix.)

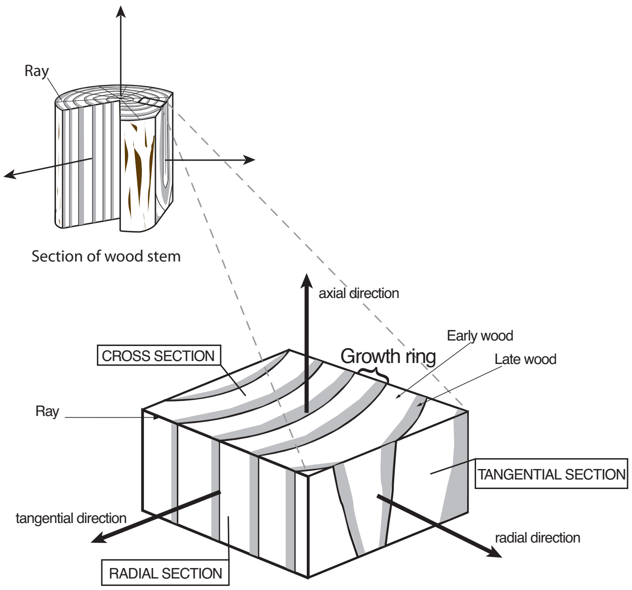

FIG. 4. Orientation of a block of wood and the three sections of the wood: transversal (cross), tangential, and radial (English version of Alix, 2001: Chap. 4, Fig, 15).

marks and sometimes threads indicating feathering or preserved feathers directly attached to the wood or found in close association, or both (Figs. 2 and 3). Most of the shafts were found in direct association with or very near arrow points. When the arrow points are of organic material, their ^{14}C dates overlap the dates of the nearby wooden shafts.

The arrow shafts and points mostly span the last 1000 years. However, one potential arrow shaft is about 2000 years older, which raises questions concerning the development of archery in the Canadian Subarctic or denotes problems with the arrow shaft identification (Hare et al., 2004:268).

Analytical Procedure for Wooden Arrow Shafts

The two collections were analyzed in both Whitehorse and Yellowknife during 2005 – 10. The lead author met with her local collaborators and co-authors in each location. In January 2010, the four authors met in Whitehorse and brought together arrows from both ice patch regions for comparison.

Wood identification to species was first undertaken by Gregory Young from the Canadian Conservation Institute in Ottawa (Young, 2000a) for objects from the Yukon Territory ice patches, and by Les Jozsa of Forintek in Vancouver for the first wooden artifact found in the Northwest Territories ice patches. Subsequently, the lead author of the present article performed all wood identifications.

During each meeting in Whitehorse and Yellowknife, the lead author sketched the artifacts and described them macroscopically in terms of morphological, technical, and physical characteristics. She then photographed and sampled them for species identification. The range of macroscopic information recorded includes:

1) Growth rings: regularity, curvature, and width of annual growth rings and their orientation in relation to the main axis of the wood (Fig. 4) and the face of the object (the shafts are placed with their proximal end lying flat on a surface as in Figs. 2 and 3);
2) Knots: presence and location of knots and other defects;
3) Grain: straightness and the presence or absence of cross grain;
4) Technology: morphological and technical details, such as cut marks, lashing marks, and attributes of the hafting, fletching and nock ends.

The wood of all arrow shafts but one was radiocarbon dated by Beta Analytic in Florida, and the remaining shaft, by the University of Waikato (Wk) in New Zealand (Table 2). Wood dust or shavings were drilled or cut through the side or ends of the main body of the artifact. In some cases, more than one date was obtained for a given arrow shaft. Radiocarbon dates were then calibrated using OxCal4.1 (Bronk Ramsey, 2009) and the INTCAL09 dataset (Reimer et al., 2009).

Microscopic identification follows standard terminology (IAWA Committee, 1989, 2004) and standard procedure of observing the wood in its three main directions and corresponding sections, transversal, tangential, and radial (Fig. 4). Small slivers of wood were hand-cut or shaved off the surface of the artifacts with a razor blade and placed on glass slides. In some cases, tiny chunks could be detached from the main objects and put into plastic vials for later slicing. Samples were taken from places on the artifacts that were deemed the least damageable and preserved the integrity of the nocks, distal hafting features, and lashing marks. Consequently, it was not always possible to sample cross sections because cutting across the grain of the wood would have damaged the original shape or cut marks left on the artifact's ends.

Locations of the cut or detached samples were recorded on the sketch of the artifact. Wood samples were observed by transmitted light microscopy at various magnifications (40×, 100×, 400×, and occasionally 1000×), and key characteristics were microphotographed. All samples were kept and would be available if requested from the lead author. Some samples were permanently mounted, and a collection of slides from artifacts of the southern Yukon ice patches is deposited with Heritage Resources, Department of Tourism and Culture, of the Government of Yukon in Whitehorse.

Wood identifications reported in this article are based on comparisons of anatomical structures with existing reference collections at DendroArch Unlimited in Fairbanks and on criteria available in manuals, including Jacquiot (1955), Panshin and de Zeeuw (1970), Schweingruber (1978), Friedman (1978), and Benkova and Schweingruber (2004). Wood was identified mostly to the genus level, e.g., such as *Betula* sp., because for the most part it is not possible to distinguish species from one another. Consequently, more specific identifications such as *Betula neoalaskana* are suggestions based on macroscopic characteristics and known native species of the boreal and spruce-hemlock coastal forests of northwestern North America. In such cases, the result is noted *Betula* sp. cf. *B. neoalaskana* (Alaska paper birch).

Theoretical Adequacy of the Wood of Arrow Shafts

An arrow can be described in seven parts or divisions: (1) the shaft or stele; (2) the shaftment, "the part of the shaft upon which the feather is fastened"; (3) the feathering; (4) the nock "or posterior end of the arrow seized by the fingers in releasing"; (5) the notch "or cut made at the end of the arrow to receive the string" (Mason, 1894:650); (6) the foreshaft; and (7) the head. In this article, we grouped these seven parts into four: 1) the head, which can be composite with a foreshaft (organic head hafted with a stone, bone, or wood point); 2) the shaft itself, also called the stele; 3) the fletching, which includes Mason's shaftment and feathering; and 4) the nock at the proximal end of the arrow, which includes the nock itself and the cut that Mason (1894:650) calls the notch.

The efficiency of an arrow varies in relation to the effect wanted by its user: precision, shooting range, and penetration (Christenson, 1997:137–138). But no matter how it will be used, the arrow and thus its shaft must have a certain elasticity and lightness while remaining strong and resilient. There is a known relationship between weight of the arrow and depth of penetration (Christenson, 1997). The material used must also remain as stable as possible so as to avoid change in the straightness of the shaft when humidity conditions vary (Beckhoff, 1965). Wood is by nature a hygroscopic material, which means that it has the property to "attract moisture from the surrounding atmosphere and to hold it in the form of liquid water or water vapor" (Tsoumis, 1991:128). Consequently, its responses to mechanical stresses change with changing humidity (Tsoumis, 1991). When the wood dries, shrinkage is not identical in tangential and radial directions and can lead to warping of the wood. A wood is stable when it has a low variation between its radial and tangential shrinkage (values given in percentage at a given moisture level).

The sensitivity of wood to moisture most likely explains why well-seasoned wood showing low shrinkage characteristics has been often preferred to make shafts. Drucker (1951:31) reports that the Nootka people of the Northwest coast preferred "old, well-seasoned wood from broken canoe or old house planks" and Osgood (1937:88) that the Kachemak Bay Tanaina in southern Alaska made "arrows of various length[s]… preferably from cedar which is picked up as driftwood." In Interior Alaska, Upper Tanana elders recall that "the only material used for arrow shafts was well seasoned spruce wood … [and that] selected living trees would be debarked and left standing in place for a minimum of three years to dry and age" (Vitt, 1971:77–78).

An arrow's characteristics are closely linked to the bow that shoots it. Arrow flex results from the power of the bow as well as the length and the weight of the shaft (Beckhoff, 1965:52). The flexibility of the wood, or its ability to return to its original state once the strain is over, is expressed by the modulus of elasticity, or Young's modulus, in which the higher the value, the stiffer the wood (Tsoumis, 1991:161). Because of the specificity of the arrow flight, it is necessary to combine this value of elasticity with the specific weight of the wood (defined as the weight per unit volume) and its stability (expressed by the percentage of shrinkage in the radial and tangential direction) at a given moisture content, in order to estimate the wood's suitability for an arrow's particular function (Beckhoff, 1965).

Rating Wood Species for Arrow Making: Beckhoff's Formula

The German prehistorian Klaus Beckhoff (1965) created an adaptability coefficient or index (δ') for different wood types used for shaft making in the prehistory of Western Europe. Thinking about wood and arrows in a new way for his time, he based this first index on the physical characteristics of elasticity, weight, and stability related to arrow flight. Subsequently, he thought to include some structural characteristics of wood that are related to the processes by which shafts were made (Beckhoff, 1965:56–58) and determined that straightness of grain and ease of splitting would have been two critical selection criteria. He considered straight grain more important than ease of splitting and gave it more weight (see formula of the index in Table 3: notes c–f), but ease in splitting staves of straight wood would have sped the making of the shafts. Indeed, Yup'ik traditional carvers today still pay attention to the splitting quality of a wood when producing staves for making shafts and fish traps (Alix, 2007). Adding these additional structural criteria, Beckhoff established a second and final suitability index that he calls δ (see Table 3: note f) so as to grade the different wood species and compare them.

Using Beckhoff's formulas, we calculated the adaptability coefficients for species we knew had been used for arrow making in northwestern North America (Table 1). These included species of the boreal forest and the spruce-hemlock forest of southeastern Alaska for which mechanical strength values were available (Table 3). The evaluation of their relative grain straightness and cleavability was established on the basis of observations reported in U.S. Department of Agriculture publications (Anonymous, 1963; Alden, 1995, 1997). However, one has to keep in mind that some boreal species such as spruce and birch would be rated by traditional users and carvers as having very straight grain with a very good cleavability as long as one knew to test and select the "right" wood or the tree with the right properties (Alix, 2007). Consequently, the final value of δ would probably rise if it were calculated on the basis of tests done for these specifically chosen trees. Table 3 with its calculated values is thus presented here as a first comparative evaluation of the potential adequacy of wood species that would have been available in the surrounding regions of the ice patches. It should be used as such until more proper mechanical tests of specific wood types are done.

TABLE 3. Wood adequacy to the function of arrow shaft according to Beckhoff's formulas. Mechanical values of the wood species taken from Alden (1995, 1997) and Anonymous (1963).

Genera or common name	Species	Young's Modulus[a] (E) in kg/cm^2	Specific weight[a] (r_{15}) in g/cm^3	Radial shrinkage (α_r) in %[b]	Tangential shrinkage (α_t) in %	α_r/α_t	δ′ first index[c]	Fiber straightness[d]	Cleavability[e]	δ final index[f]	Shock resistance[g]	Level
Picea (spruce)	*P. mariana*	113197	0.449	3.3	5.4	0.61	1.54	1	0.9	1.39	ML	Excellent
	P. glauca	100542	0.449	4.7	8.2	0.57	1.28	1	0.9	1.16	M	Very good
	P. sitchensis	110385	0.449	3.4	6	0.57	1.39	1	0.9	1.11	ML	Very good
Betula (birch)	*B. neoalaskana*	133587	0.609	6.5	9.9	0.66	1.44	1	0.9	1.30	M	Excellent
	B. papyrifera	111791	0.609	5	6.9	0.72	1.33	1	0.9	1.20	M	Excellent
Pinus (pine)	*P. contorta*	94214	0.465	3.6	5.4	0.67	1.35	1	0.9	1.22	ML	Excellent
Tsuga (hemlock)	*T. heterophylla*	114604	0.465	3.4	6.3	0.54	1.33	1	0.9	1.20	M	Excellent
	T. mertensiana	93511	0.529	4.4	7.1	0.62	1.10	1	0.9	0.99	M	Very good
Red alder	*Alnus rubra*	82262	0.449	3.5	5.8	0.60	1.11	no data	no data	–	no data	–
Red cedar	*Thuja plicata*	78043	0.368	1.9	4	0.48	1.01	1	1	1.01	L	Good
Yellow cedar	*Chamaecyparis nootkatensis*	99839	0.497	2.2	4.8	0.46	0.92	1	0.8	0.74	M	Not desirable δ′ < 1
Tamarack	*Larix laricina*	115307	0.593	3	5.9	0.51	0.99	0.8	0.9	0.71	MH	Not desirable δ′ < 1
Serviceberry	*Amelanchier* spp.[h]	132181	0.833	6.7	10.8	0.62	0.98	no data	no data	–	H	Not desirable δ′ < 1
Black willow	*Salix nigra*	71012	0.417	2.1	6.5	0.55	0.55	no data	no data	–	L	Not desirable δ′ < 1

[a] When wood is dry (at 12% humidity).

[b] At 6% humidity.

[c] Beckhoff's first index is calculated using the following formula: $\delta' = E/r_{15} * \alpha_r/\alpha_t * 10^{-5}$ (see Beckhoff, 1965:54–55).

[d] Rated as 1: regular; 0.8: medium; 0.5: irregular.

[e] Rated as 1: good; 0.9: medium; 0.8: poor.

[f] Beckhoff's final index δ is the product of δ′ and values given for fiber straightness and cleavability (see Beckhoff, 1965:56–58).

[g] H: high, M: moderate, L: low, MH: moderately high, ML: moderately low.

[h] Saskatoon berry wood was used mostly unsplit. Straight branches or saplings were used for shafts and foreshafts (see also Table 1 for use as an arrow shaft).

We calculated the δ′ index using mechanical values available for commercial wood that has grown in the more temperate regions of the United States (Alden, 1995, 1997). However, these values, and especially those of coniferous and spruce wood, are ultimately related to the conditions under which trees grew and to where the wood is taken within the stem (Jane, 1970; Sonderegger et al., 2008). In the Subarctic boreal forest, trees grow more slowly than farther south and consequently have narrower growth rings (Anonymous, 1963: Tables 2–4). Among coniferous trees and particularly among spruce trees that do not develop a lot of late wood in the growth ring (Fig. 4), slow growing conditions reduce the ratio of early wood in the ring without modifying that of late wood. Consequently, the wood produced is denser with a higher specific weight because the longitudinal fibers that form the wood are made of thicker-walled cells in the late wood than in early wood. Thus, the overall mechanical strengths of the wood can be slightly increased (Jane, 1970:266; Sonderegger et al., 2008:282). Coniferous wood from slow-grown northern boreal forest trees, if mechanically tested, would provide different, possibly higher, values than those reported in Table 3. The effect of slow growing conditions applies differently to diffuse porous deciduous woods such as birch, and the consequences for the quality of the wood are not comparable.

In elaborating a suitability index to rate the wood of arrows, Beckhoff takes into account characteristics that concern mostly the flight of the arrows and their making. According to this rating system, hunters of the Subarctic forests have used wood with good to excellent arrow-making qualities (Table 3). There is little difference among the species that have been identified in the ice patch arrow shafts (Table 4). Birch, pine, western hemlock, and black spruce are all rated excellent, while white spruce and Sitka spruce have a very good rating. The slight difference between black spruce, white spruce, and Sitka spruce is odd and again makes us question the validity of using the values of temperate commercial wood in lieu of boreal species. Today, Sitka spruce is, commercially, one of the most highly rated types of wood for modern arrow making.

In the calculation of its coefficient, Beckhoff does not take into account shock resistance or the likelihood that the shaft will break upon impact (i.e., the resilience of the wood). Yet, breaks observed on various shafts indicate that this property might have been important. For this reason, we added the qualitative value of shock resistance, as found in descriptive accounts of the different woods (Alden, 1995, 1997), to Beckhoff's criteria (Table 3). For example, white spruce has a higher shock resistance than black spruce, which might improve its adaptability index if this characteristic were taken into account.

The wood of *Salix nigra* (black willow) has the lowest δ′ of all species tested (Table 3), and Beckhoff in his original study would not have considered this wood further. In fact, none of the ice patch arrow shafts found use willow saplings or staves. The wood of unspecified willow was used only for shafts and foreshafts of atlatl darts before the introduction of the bow-and-arrow technology in the region and only in the early period of the chronology of dart shafts from the Yukon Territory ice patches (Hare et al., 2012).

The next three species that have the lowest δ′ (between 0.92 and 0.99) are yellow cedar, serviceberry, and tamarack (Table 3). Yellow cedar and tamarack both end up with a low final index (δ = 0.74 and 0.71, respectively), which makes them undesirable for arrow shafts. Interestingly, these two wood species are not mentioned as potential wood for arrow shafts in the ethnographic literature reviewed (Table 1). Serviceberry (*Amelanchier* sp.), on the other hand, ends up with a relatively low δ′ index, which cannot be transformed into a final index because we could not find data on its fiber straightness and cleavability. Unlike the other three woods just mentioned, *Amelanchier* is repeatedly reported as a wood for arrow shafts (Table 1) and was identified as the wood of a ca. 2300 ^{14}C years foreshaft (Andrews et al., 2012a), as well as a historic blunt Athapaskan arrow (Alix, 2008b). Finally, red alder with a good δ′ rating is not reported as a wood used for arrow shafts (Table 1) and was not found in either of the two ice patches. Further discussion is certainly needed about using mechanical values of commercial wood for the calculation provided in Table 3. Nevertheless, apart from *Amelanchier* and *Acer* (maple), for which we do not have appropriate mechanical values to calculate an adequacy index, the species identified as having been used for arrow shafts (Tables 2 and 4) all rated very good to excellent.

THE IDENTIFIED TAXA: CHARACTERISTICS AND POTENTIAL ORIGIN

The 27 arrow shafts found in the two ice patches regions are mainly made of spruce (*Picea* sp.) and birch (*Betula* sp.) wood (Table 4; Fig. 2a–n and Fig. 3a–f). One arrow is made of pine (*Pinus* sp. sec. *ponderosa*; Fig. 2o) and another is made of hemlock (*Tsuga* spp.; Fig. 3h). The oldest shaft is dated between 3600 ± 40 ^{14}C BP [ca. 3910 ± 175 cal BP] and 3510 ± 70 ^{14}C BP [ca. 3790 ± 185 cal BP] and was found at the Friday Creek ice patch (JcUu-1) of southwestern Yukon (Hare et al., 2004:268). The oldest shaft from the Northwest Territories ice patches is 850 ± 40 ^{14}C BP [790 ± 110 cal BP]. In southwestern Yukon, apart from the oldest possible arrow, the remaining 22 shafts are dated between 1010 ± 40 ^{14}C BP [930 ± 130 cal BP] and the early 20th century (the youngest date is 90 ± 40 ^{14}C BP), at a time when the boreal forest was in its present configuration.

As just mentioned, none of the wood species used for arrow making are inadequate since they all rated very good to excellent (between 0.99 to 1.39) according to the adaptability index formula (Table 3). We present below the physical characteristics of the wood used for the shafts and review the distribution of the different species available for each identified genus. This review allows us to discuss the potentially local or more distant origin of the wood selected for arrow shaft making.

*Spruce (*Picea *spp.)*

Over half of the arrow shafts consist of reduced and whittled staves of spruce wood (Table 4, Fig. 2a–n). The identification of spruce as opposed to larch (*Larix* sp.), a species that is anatomically very close, is based on the predominance of *Picea* type 1 and 2 pits on the wall of the ray tracheids. These pits are found predominantly in spruce wood, while larch wood tends to have more numerous *Larix*-type pits (Anagnost et al., 1994). The anatomical speciation of white spruce (*Picea glauca* (Moench) Voss) and black spruce (*P. mariana* (Mill.) Britt.) is not possible even though it was attempted in northern Quebec with an accuracy of 70% (Marguerie et al., 2000).

Given the geographical location of the ice patches (Fig. 1), the wood of the arrow shafts may be of white spruce or black spruce, but in theory, it could also be of Sitka spruce (*Picea sitchensis*). Sitka spruce does not grow in the Yukon Territory or the Northwest Territories; it is mostly restricted to coastal areas between northern California and southern Alaska. However, the presence in the ice patches of the coastal genus hemlock (*Tsuga* spp.) indicates that Sitka spruce cannot be completely excluded.

In southwestern Yukon, white spruce trees are much more abundant than black spruce trees, which are almost absent (Johnson and Raup, 1964; Lacourse and Gajewski, 2000). Black spruces tend to become more numerous as one goes north of Kluane Lake, "at the head of Talbot Arm and in the forests northward" and west past the White River towards the Alaskan border (Johnson and Raup, 1964:81) (Fig. 1). By contrast, white spruce trees are quite common throughout the region, and they grow tallest, widest, and with the straightest grain on the floodplains of the larger rivers. Considering the characteristically straight grain of all spruce arrow shafts, the wood of such trees would be a likely candidate. At the same time, the average growth ring width of the 16 spruce arrow shafts is 0.3 mm. Only one arrow (JhVl-2:1) has growth rings larger than 0.5 mm, averaging 0.8 mm. The predominance of very narrow growth rings suggests the selection of slow-growth wood. Such wood is found in black spruce, which tends to have very narrow growth rings (Viereck and Little, 2007) or in tree-line white spruce trees, although the straight grain characteristic of the arrow wood does not necessarily correspond to wood from tree-line trees. Large, dominant white spruce

TABLE 4. Taxa identified for the arrow shafts, by region.

Common name	Scientific name	SW Yukon Territory	Northwest Territories	Total
Spruce	*Picea* sp.	15	1	16
Logdepole pine	*Pinus* sp. cf. *P. contorta*	1		1
Hemlock	*Tsuga* sp.	1		1
Paper birch	*Betula* sp. cf. *B. neoalaskana*	6	3	9
Total		23	4	27

from low-elevation stands or river floodplains in the southwestern Yukon and Alaska show higher rates of growth; data for the last 200 years of growth show that average ring width ranges from 0.7 mm to slightly above 1 mm (Barber et al., 2000; Zalatan and Gajewski, 2005; Winslow, 2008). However, narrow rings can be found within portions of these old upland and lowland white spruce trees, at the periphery of the trunk or within the heartwood.

Two-thirds of the spruce shafts (n = 11) are made of wood bearing small knots (generally less than 1 mm in diameter, with the largest just over 3 mm). In three cases, these knots are located where the shaft is broken. In other cases, knots are near the distal or proximal ends. When knots are numerous (mostly in two cases), they are spread throughout the length of the shaft. These observations show that only very small knots were left in the wood used for shafts and, when unavoidable, they were left as much as possible in areas where they would be covered by sinew: at the distal end or near the proximal end where sinew is used for lashing the feathers.

In four cases, the grain of the wood becomes sinuous because a larger knot was present in the original piece of wood that was split down to a stave and then rounded into a shaft. Overall, it is safe to say that the presence of knots did not affect the function of the shafts beyond normal wear and that the shafts were preferably made with knotless and tight, straight-grained spruce wood. Trees tend to have wood free of knots in the lower part of their trunk, where branches are minimal or absent. The characteristics of the wood—straightness of grain, narrow growth rings, and the near absence of knots—suggest that spruce arrow wood was taken from within the lower trunk of specific mature, slow-grown upland and lowland white spruce or from straight-grain black spruce trees. Black spruce wood rated very high in Beckhoff's rating although white spruce, with a slightly lower δ index, has a higher resilience than black spruce.

*Birch (*Betula *sp.)*

Of the nine arrow shafts made of staves of birch wood (Fig. 3a–g), only two have knots. As in the spruce arrow shafts, these knots are small and were left in areas likely to have been covered by sinew lashing. A small knot is located at the beveled proximal end of JbVa-1:13 (Fig. 3g), and a small knot is located near the distal end of JiUl-1:2 (Fig. 3f). Overall, birch arrow shafts tend to have even fewer knots than spruce arrow shafts. The annual growth rings of the birch wood are regularly spaced, and their widths average 0.61 mm, or 0.3 mm larger than those in the wood of the spruce arrow shafts. The number of birch arrow shafts is low; nevertheless, we note that the shafts of birch wood from the Northwest Territories have narrower growth rings (average is 0.45 mm) than those of southwestern Yukon (0.7 mm). The average growth rings for the arrow shafts of the Yukon are in accordance with those recorded for the birch wood used in dart shafts over the preceding 6000 years (Hare et al., 2004; Alix, 2006:7). The straightness of the grain, lack of knots, and absence of growth ring curvature suggests that the wood of larger trunks of birch, such as Alaska paper birch (*Betula neoalaskana* Sarg.) as opposed to shrub birch (*Betula glandulosa* Michx.), was used to make arrow shafts.

Like black spruce, Alaska paper birch trees are mostly absent from the region of Kluane Lake in the southwestern Yukon (Fig. 1). When present, they are "poorly formed trees" that would not produce the straight grain and mostly knotless wood used for the arrow shafts. Birch trees are found in greater numbers in the mountains to the north of Kluane Lake and "in appreciable quantity west of the White River" (Johnson and Raup, 1964:81). East of the Mackenzie Mountains, in the central Mackenzie River valley, paper birch is found in association with black spruce and tamarack (*Larix laricina*), mostly on south-facing slopes where the active layer is thicker and permafrost is at a greater depth (Crampton, 1974).

*Pine (*Pinus *sp.) and Hemlock (*Tsuga *spp.)*

Besides the arrow shafts made of the two main wood species, two complete shafts (JbVa-1:3 and JcUu-2:17) were identified respectively as lodgepole pine (*Pinus* sp. [sec. *ponderosa*] cf. *P. contorta*) and hemlock (*Tsuga* spp.) (Figs. 2o and 3h). Like the other shafts, both are made of straight-grained and knotless wood staves. Average width of growth rings is 0.5 mm in the lodgepole pine shaft and 0.7 mm in the hemlock shaft.

The pine wood is characterized by reticulate thickening of the ray tracheids, as seen in the radial section; two to four pinoid pits per cross field; and thin epithelial cells in resin canals and uniseriate rays. These criteria correspond to a pine of the *ponderosa* section, a subgenus that includes lodgepole pine (*Pinus contorta* Dougl. ex. Loudon). This species is native to the Yukon and relatively widespread in its southwestern part, although it rapidly reaches its limit of growth towards the west of the Shakwak valley (Johnson and Raup, 1964). In the central part of the Yukon, the lodgepole pine reaches 64° N, just south of the Mackenzie Mountains (Cody, 2000).

JbVa-1:3 is the only object of pine that was found in the ice patches of the southwestern Yukon; none was found in the Mackenzie Mountains. Pollen records of southwestern Yukon show *Pinus* pollen present for the last 5000 years, with an increase following the deposition of the White River ash (Wang and Geurts, 1991:189; Lacourse and Gajewski, 2000:31). Thus, the near absence of pine in the record of arrow shafts (or for that matter, of dart shafts) of the preceding 4000 years, cannot be explained by its absence on the landscape. Makers of arrow shafts for caribou hunting have preferred spruce and birch to lodgepole pine even though the three species show comparable suitability values (Table 3).

The wood of JcUu-2:17 is characterized microscopically by the absence of resin canals and the presence of uniseriate rays, marginal ray tracheids, and two to four piceoid pits per cross field. It is identified as hemlock, *Tsuga* spp. No hemlock trees grow in the Yukon. However, two species that cannot be distinguished anatomically are found along the coast of neighboring southeastern Alaska and British Columbia (Fig. 1): western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and mountain hemlock (*Tsuga mertensiana* (Bon.) Carrière). Mountain hemlock replaces western hemlock above 1000 m, where it turns into a shrub near the tree line (Viereck and Little, 2007:59–63).

The straightness of the grain, the lack of knots along the shaft, and the regular and relatively narrow growth rings averaging 0.5 mm all suggest this wood stave came from a large tree that probably grew below 1000 m. Like the pine shaft, JcUu-2:17 is the only hemlock object found in the western Canadian Subarctic ice patches. It suggests specific wood selection and its circulation as raw material or a transformed object, possibly through travel of its owner.

THE SHAFTS: MORPHOMETRY AND CHARACTERISTICS

Because of the multiplicity of arrow point types, the distal end (hafting end) of the shaft is thought to be the part most likely to vary. The proximal end of the arrow, with its nock and fletching, is also subject to variation. The notch, or cut, forming a 'U' or 'V' is often reported in the literature. However, as described below, the shape and dimensions of the shaft at the nock end is a more distinctive characteristic than the shape of the cut. Remains of fletching are rare in the archaeological record.

Morphometry

The shafts are long cylinders, tapered more or less strongly at one or both ends with a slight oval or fully round cross section. According to some arrow makers (Cosgrove, 2000), the general shape and taper of a shaft is related to the shooting goal of the archer and the speed of the arrow. A barreled shaft (tapered at both ends) is said to be used for "target archery and flight shooting and tends to be less durable" (Cosgrove, 2000:228). Another described arrow type is:

> a tapered shaft which is narrower at the nock end and wider at the point end. The tapering of the shaft allows the nock end of the arrow to clear the bow more easily resulting in a better arrow flight. This eliminates drag, the fletching lasts longer and also reduces weight – which produces a faster arrow. The tapering allows the arrow a much quicker recovery rate after it bends around the handle of the bow. The faster the recovery rate, the more stable the arrow. (Cosgrove, 2000:228)

Of the 15 complete and 2 nearly complete shafts under examination, 13 are barreled and 4 are tapered. All four tapered shafts are made of spruce or hemlock and were found at the Alligator Lake ice patch JcUu-2 in southwestern Yukon, where the radiocarbon dates of the spruce shafts overlap at some point between 300 and 100 cal BP. As we will see below, the hemlock arrow shaft is slightly older and differs by several other characteristics.

The shape of the cross section is best illustrated by the ratio of thickness to width measured at the maximum width of the stele. All the arrow shafts but one have a ratio between 0.9 and 1.1, indicating near-perfect roundness. The spruce arrow shaft JhVl-4:3 (Fig. 2b) is the exception, with a ratio of 0.8 and thus a more oval-shaped cross section. Maximum diameters range between 7.4 and 10.1 mm and average 8.6 mm. However, the range of variation is partly due to the state of preservation of some of the shafts. Indeed, the smallest diameter corresponds to a highly weathered arrow shaft (JbVa-1:5; Fig. 2f), while the largest (JbVa-1:1; Fig. 2g) is measured on one of the best-preserved shafts. Thus in reality, maximum diameters should be seen as varying between 8 and 10 mm, with two-thirds of the shafts having a diameter of 8 to 9 mm. Maximum diameter shows no correlation to either length or wood taxa. Interestingly, in his discussion of Old World Paleolithic arrow shafts, Beckhoff (1965:52 and note 8) explains the physical necessity for shafts made of pine or other light wood to have diameters between 8 and 9.5 mm, as well as the relationship between the degree of flexibility of the shaft, the power of the bow, and the length and weight of the shaft. We note here that the 3500 to 3600 ^{14}C years old arrow (JcUu-1:1) has a 9.6 mm maximum diameter, which puts it in the upper end of the diameter range.

Length is the dimension that varies the most in the collection of complete arrow shafts, with a ratio of almost 1 to 2 between the longest (101 cm) and the shortest (52 cm) (Table 2). The longest arrows are made of birch and hemlock: their lengths range from 72 to 101 cm, while those of the spruce and pine arrow shafts range from 52.2 cm to 72 cm (Fig. 5). Length is not correlated to the age of the arrow shaft, with the possible exception of the oldest shaft (JcUu-1:1), which is incomplete but still measures 100 cm. However, shaft length is also related to the length of the arrowhead hafted to the shaft, which in the case of antler

TABLE 5. Characteristics of the proximal and distal ends of the arrow shafts.

	Proximal end				Distal end/hafting			
Material	U	Ψ	V	n/a or bevel	Closed socket	Open socket	Split	n/a or bevel
Picea sp.	5	4	2	5	12	2		2
Pinus sp. cf. *P. contorta*		1			1			
Tsuga sp.		1					1	
Betula sp. cf. *B. neoalaskana*	1	3		4			6	3
Total	6	9	2	9	13	2	7	5

arrowheads can add 10 to 20 cm to the total length of the arrow. As mentioned previously, length is ultimately related to the weight and draw of the bow that will shoot the arrow, thus to the height, arm length, and strength of the archer (see Osgood, 1971:71).

Balance is another important element of the shaft. Balance is expressed as the ratio of the total length of the shaft to the length from distal end to maximum diameter. In most cases, the balance point is located within the first half of the shaft (from the distal end). However, in the case of three complete and one nearly complete arrow shafts, the balance point is closer to the proximal end than to the distal end (Fig. 5). This characteristic is found in three birch arrow shafts (Fig. 3a–c); it is also found in one spruce arrow (JbVa-1:1; Fig. 2g) that has a balance point close to the mid-point of the shaft. The nearly complete birch arrow shaft JcUu-2:25 (Fig. 3e) would clearly be within this group if it had been found complete. By contrast, one birch arrow shaft JiUl-1:2 (Fig. 3f) is balanced with a balance point in the lower distal end like the rest of the coniferous (spruce and pine) arrow shafts (Fig. 5). The dimensions of the oldest arrow shaft (JcUu-1:1) suggest that, if it were complete, its balance point would be located in its lower distal end as well.

The Nock End of the Shaft

The notch of the nock part of an arrow shaft is usually described as a ‘U’ or ‘V’. Here we add a third type that we call “open U.” We represent the open U type by the letter psi (Ψ) after Mason (1894:664), who describes a similar notch (see Table 2: note 4). In the Ψ notch, the bottom of the cut is round, but the sides are flared. The U and Ψ types are the most common types (Table 5, Fig. 6), and only two shafts (JhVl-4:8 and JbVa-1:1) have a V nock. The depth of the notch, whatever its shape, is somewhat proportional to its width, ranging from 1.7 mm to 5.8 mm. No obvious correlation was found between the type of nock and the general dimensions of the shafts or their dates.

Another characteristic of the nock end has to do with its width and cross section in relation to the width and cross section of the stele. This relationship is ultimately more important than the shape of the notch because it has implications for arrow release (the way the arrow is held when the bowstring is drawn), which has been reported to fall into different types involving the use of specific fingers (see Morse, 1885; Kroeber, 1927; McKennan, 1959:56–57).

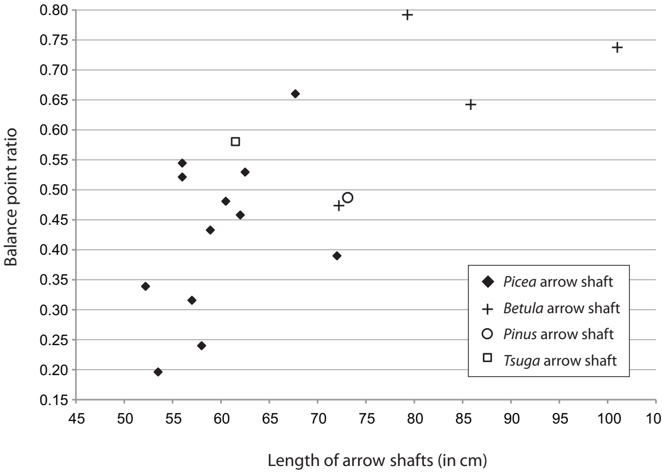

FIG. 5. Length of complete and nearly complete arrow shafts, by species, and balance index (the ratio of the distance of the largest diameter from the distal end to the total length of the shaft).

Two relevant traits characterize the ice patch arrow shafts. First, the width of the nock end is always smaller and narrower than that of the stele (by 1/3 or 1/4 of the maximum width). Second, while the nock is narrower than the stele, it is not less thick. In fact, in most cases, the section of the shaft at the nock is round or slightly oval. As for the main part of the shaft, the ratio of thickness to width varies between 0.9 and 1, which corresponds to an almost round cross section. Only two shafts (JbVa-1:3 and JbVa-1:5) have a more oval nock end cross section, with a thickness: width ratio of 0.8.

Finally, nine arrow shafts have a strong (n = 5) or slight (n = 4) constriction just below the nock and just above the area where fletching lashing marks are found (Fig. 6). This feature, which is particularly visible in three of the birch arrow shafts (JcUu-2:26, JcUu-2:25, KhTe-2:1–6; Fig. 3d, e, b) and two spruce arrow shafts (JcUu-2:5/JcUu-1:3, JhVl-7:2; Fig. 2l, h), means that the diameter of the shaft in this area is clearly narrower than either the notch end or the stele. Another eight arrow shafts show no clear constriction, but instead gradually widen toward their maximum width (Fig. 6). Among these are the pine and hemlock arrow shafts. Once again, no correlation could be found between the presence of the constriction and the type of notch or cut or the dating of the shafts, but it is possible the sample size is still too small for us to detect patterns.

These observations about the nock part of the arrow shafts, however, led to the characterization of a Subarctic

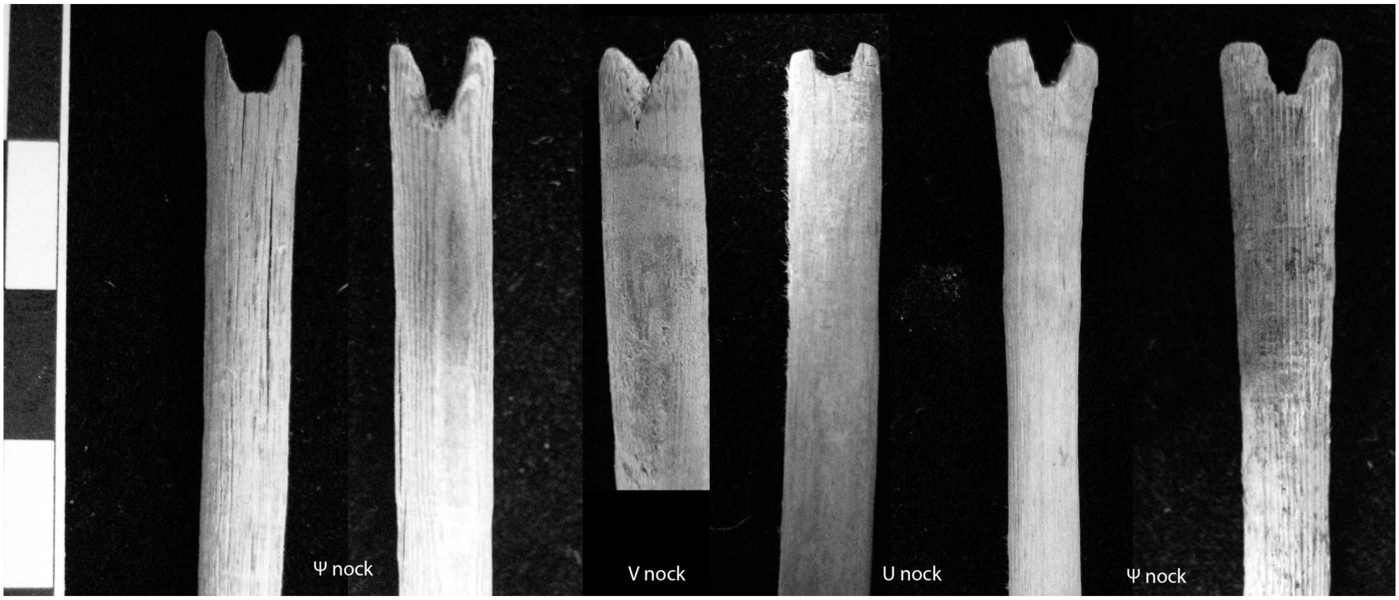

FIG. 6. Proximal ends of arrow shafts showing the three notch cut types: (left to right) JbVa-1:3 (Ψ), JgVe-1:2 (Ψ), JbVa-1:1 (V), JhVl-7:1 (U), JcUu-2:26 (Ψ), JcUu-2:5 (Ψ).

type of nock end that lasted a thousand years. In order to test the hypothesis of this nock end as a distinctive type, we compared the ice patch data set to a collection of proximal end fragments of arrow shafts from seven Arctic sites of the Thule culture. These sites, located between the north coast of Alaska and the eastern Canadian High Arctic, are dated from the 12th to the 15th century AD (Alix, 2001, 2009a).

Complete arrow shafts are rare in these house and midden contexts, although shaft sections are common. For the present comparison, from a data set of more than 70 confirmed arrow shaft fragments, we kept 16 proximal fragments with a minimum length of 16 cm. The Thule culture arrow shafts have no constriction, but they show a gradual decrease of the width of the stele as the thickness increases. While the nock end of the Subarctic arrow shaft is always narrower than the maximum width of the stele, the nock end of the Arctic arrow is always larger or equal to the maximum stele width. In all but one of the Thule arrow shafts, the proximal or nock part of the shaft is wider and thinner than the stele. Thus, the larger width of the proximal end is accompanied by a characteristic flattening of the shaft that produces a strongly oval or sometimes strictly flattened cross section (Alix, 2001, Vol. 2:3–5). In fact, the flattening of the nock end is visible in all 70 proximal ends of arrow shafts that were analyzed in the Arctic data set. The Arctic shafts have a nock ratio (thickness to width) between 0.2 and 0.6, while the the Subarctic arrow shafts mostly had a ratio between 0.9 and 1 (Fig. 7). At the same time, the width of the Subarctic nock is strictly narrower (by one-half or one-third) than that of the Arctic arrows (Fig. 7). The two sets of arrow shafts are truly distinct on the basis of the nock end.

As mentioned above, the shape of the nock may be related to the position of the hand, depending on which fingers are holding the shaft and how. The flattening of the Arctic arrow has been related to the use of what is called the "Mediterranean release." This technique involves holding the nock between the index and middle fingers and pulling the string with the same fingers; the thumb is not used at all (Morse, 1885:14–15). This release differs from the "pinch release" (also called primary, secondary, and tertiary release), in which the thumb and the index finger are used to hold the nock of the shaft (for a more detailed description see Morse, 1885; Kroeber, 1927). According to ethnographic accounts, both the "pinch" and the "Mediterranean" releases have been observed historically among Athapaskans and non Eskimo-Aleut groups of the northwestern interior and coastal Subarctic (Kroeber, 1927; McKennan, 1959:56–57). The relationship between the shape and dimensions of the nock and the release type has never been observed systematically; it is not resolved by reference to ethnographic reports on release types and should be explored in future research.

Fletching of the Proximal End

Two complete arrow shafts from southwestern Yukon Territory (JcUu-2:16 and JcUu-2:19, Fig. 2c, d) and one from the Northwest Territories (KhTe-2:1-6, Fig. 3b) were found with their associated feathers. The feathers of JcUu-2:16 and 19 are still attached to the shaft with sinew, while the feathers of KhTe-2:1-6 were found lying beside the six fragments of this complete arrow with no associated sinew thread (see Andrews et al., 2012a: Fig. 8).

In all three shafts, the fletching consists of three feathers, the vanes of which have been trimmed on each side of the quill (Fig. 8). Trimming is more pronounced on one side than on the other. Lashing marks below the notch end and farther down the stele are preserved on an additional eight shafts. Distances between the two sets of lashing marks and the length of the well-preserved feathers from KhTe-2 show

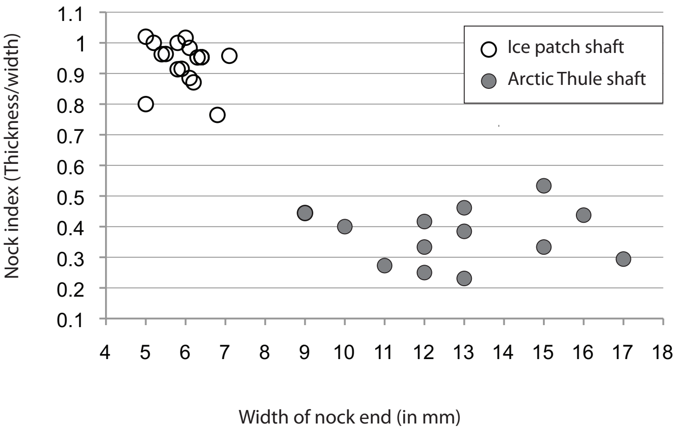

FIG. 7. Width of nock end and nock index of Subarctic and Arctic arrow shafts (nock index is the ratio of nock thickness to nock width).

FIG. 8. Detail of preserved feathers on shaft JcUu-2:16, showing the two closer feather quills. Scale bar in cm.

that the fletching covered 14 to 34 cm of the shafts (mean = 21 cm; n = 11). Depending on the arrow, this distance corresponds to one-fourth to more than one-third of the total length of the shafts. The longest fletching is found on one of the long birch arrow shafts (JcUu-2:25, Fig. 3e). Once again, there seems to be no relationship between the length of the feathers and the age of the shaft, as the longest and the shortest feathers are found on shafts of similar radiocarbon ages. These dimensions are slightly larger than those reported in the late 19th to early 20th century ethnographic literature for the western Subarctic, which vary mostly between 10 and 20 cm (see Osgood, 1936, 1937, 1940; McKennan, 1959). For example, McKennan (1959:51), commenting on Dene fletching procedure in the Upper Tanana region, states that "three split feathers are attached radially by sinew lashings; such feathering usually extends for 4 or 5 inches [10.2 to 12.7 cm], although on an arrow designed for big game, 7-inch [17.8 cm] feathers are used. Eagle feathers are preferred although hawk and occasionally, swan feathers are also used." The split feathers of the 440 radiocarbon-year-old arrow shaft JbVa-1:1 (Fig. 2g) were identified as eagle feathers (Dove et al., 2005), indicating the antiquity of technological traditions transmitted orally and reported on by early ethnographers and present-day oral history.

The two arrows JcUu-2:16 (Fig. 2c) and JcUu-2:19 (Fig. 2d) had the quills of the feathers still lashed with sinew onto the wooden shaft; the sinew thread had been subsequently covered with ocher. In both cases, two of the three quills are closer than the third one, so that one feather appears as if on the bottom and the two others on top, or vice versa (Fig. 8).

Osgood (1936, 1940) describes a similar distribution of feathers around the circumference of shafts for both the Gwitch'in of the Fort Yukon region in interior Alaska and the Deg Hit'an of the lower Yukon River:

> Strips about 6 inches long [15.24 cm] of split eagle or hawk feathers are tied close to the nock of the arrow. A little pitch aids in sticking them on and they are tied at both ends with sinew. Three rows of feathering are used on each arrow, two a little closer on top, and one underneath. They are not twisted. (Osgood, 1936:83)

> When three vanes are used, one is on the bottom and the other two on top, rather than having a 120° angle between them. (Osgood, 1940:203)

Incidentally, JcUu-2:16 and JcUu-2:19 are among the youngest arrows of the collection since they are dated to the last 250 years BP. They provide evidence of continuity of technical knowledge over at least 300 years of Athapaskan traditions. The feathers, however, could not be identified (Dove et al., 2005).

Experimental testing that takes into account the length and positioning of the feathers on the shaft might improve our understanding of the advantages of having long feathers and their consequences on the flight of the arrow. According to modern and traditionalist arrow and bow maker Mickey Lotz (2008:222), "fletching provided stabilization by creating drag […] keeping the rear of the arrow traveling in line with the forward end." He argues further that

> the higher and longer the feather, the more drag it exerted. Fletching size is often related to point size. If something large was attached to the front of the arrow, something large was also needed to control the rear of the arrow. Feather size and number could also be used to control the speed and distance an arrow flew. The bigger the feather, the slower the arrow speed and shorter the arrow's distance. (Lotz, 2008:222–223)

Distal End and Hafting Type

The distal ends of the arrow shafts show two main types of hafting apparatus, "sockets" and "splits" (Table 5). Incidentally, these hafting types are related to different forms and raw materials of arrowheads. Indeed, two main types of arrowheads have been found so far in association with the arrow shafts: 1) antler arrowheads with or without tangs and 2) stone arrowheads with lateral notches.

Most sockets (n = 13) are cavities that were carved out or, more often than not, formed by forcing a bone or antler

FIG. 9. Detail of open socket hafting type with shoulderless arrowhead (upper: JhVl-4:3; lower: JhVl-4:8). Scale bar in cm.

arrowhead with a conical tang into the wood of the shaft. Such forcing often results in a characteristic “cross-split” at the distal end (Fig. 2k–o) and is generally associated with lashing marks 2 to 5 cm or more up from the end. In this hafting type, the shaft made of spruce or pine was cut straight or slightly slanted at its distal end, and the socket forced or carved is more than 2 cm deep.

Two spruce shafts (JhVl-4:3 and JhVl-4:8, Fig. 2b, e) found together with an antler arrowhead at the East Gladstone ice patch show a variant of the socket hafting type that we call here “open socket” (Table 5, Fig. 9). It is a beveled groove 3.5–5.5 cm long, which is as wide as the distal end of the shaft. The barbless willow leaf–shaped antler arrowhead (Fig. 2b) has a tapered, shoulderless proximal end that fits perfectly into the groove (Fig. 9) and was lashed, probably with sinew. The tip of the distal end shows a slanted cross-cut on both shafts, and there is a slight knob on the opposite face of JhVl-4:3. The two shafts are strongly similar, and the arrowhead fits interchangeably in both sockets, suggesting they may have come from the same quiver. The resemblance of these two arrows goes as far as having a very similar right-angle break that did not separate the two fragments completely. Unfortunately, the dates obtained on the shafts cannot confirm that they are contemporaneous and may suggest the limited efficacy of radiocarbon dating recent material.

Seven arrow shafts have a hafting apparatus that consists of a simple split (Table 5). The splits follow the grain of the wood and often the boundary of a growth ring. In six of these seven shafts, the split is not extensive, covering about 2.5 cm (Fig. 3a–d, f, g). This small and simple split is found only on birch arrow shafts: three from the Northwest Territories, two of which are hafted with a chert notched point (Fig. 3a, b and see Andrews at al., 2012a: Fig. 6), and three of the six from the Yukon Territory (Fig. 3d, f, g), the other three having been cut or broken with no proper data on their hafting end (e.g., Fig. 3e).

No stone arrow point has been found so far in the ice patches of southwestern Yukon. However, the dimension and shape of splits of most birch arrow shafts look so much alike that they suggest similar stone arrowheads. The only exception is arrow shaft JiUl-1:2, for which we cannot completely exclude that the slightly broken distal split may have received the tang of the antler arrowhead found nearby. The date on the arrowhead overlaps with that of the shaft within two standard deviations. Interestingly, this is the only birch shaft for which balance point and length are closer to those of the spruce shafts.

Three of the birch arrow shafts have either the distal or proximal end fashioned with a simple or double bevel (Fig. 10, Fig. 3c, e, g). We interpret these bevels as potential repairs and the incomplete arrow shafts as composite sections (for splicing). In the case of JcUu-2:25 (Figs. 3e, 10), the balance point of the shaft and its similarity in shape to JcUu-26 together suggest that the bevel is not a hafting end, but rather a splice end for joining two shaft sections.

A final type of split is found on the hemlock arrow shaft JcUu-2:17 (Fig. 3h), which has an antler arrowhead still hafted to its distal end. The tip of the arrowhead is broken, but its proximal end shows a double-bevel tang with no shoulder that is strikingly different from the bone or antler arrowheads hafted onto the spruce and pine arrow shafts. The split on the wooden shaft is much more extensive than that of the birch shaft, covering more than 10 cm, and is adapted to the double-bevel tang of the antler arrowhead (Fig. 11). So far, this hafting technique has been found only on the hemlock arrow shaft and is unique in the collection of arrow shafts or heads from the two ice patch regions.

The number of shafts studied here, while remarkable, is still too small to allow meaningful and clear correlations between the characteristics observed at the proximal and distal ends. This is unlike work conducted in Norway, where a typo-chronology has been built based on a large number of arrow shafts (Farbregd, 2009). In Norway during the early Iron Age period, two types of arrow shafts co-existed as well. They are distinguished by the characteristics of their distal and proximal ends and their wood types (Farbregd, 2009: Fig. 9).

In the present collection, no correlation can be made between the type of nock end—U, open U (Ψ) or the rare V—and the hafting type, except that only U and Ψ are found on birch arrow shafts. The U and Ψ types also tend to have a constricted nock end (Fig. 6). The V nock is associated with the open socket shaft JhVl-4:8, and unfortunately, the second open socket shaft (JhVl-4:3) is missing its proximal end.

While no clear correlation could be found between the type of hafting and the time interval during which the arrows were likely made, we note that the open sockets and the well-carved closed socket are dated to the last 300 radiocarbon years (Fig. 12). Overall, the shafts do show variations in their morphometry, which are related to the wood species and to the type and form of arrowhead hafted to the shaft (Fig. 12). Ultimately, characteristics of the shafts are related to the bows that shot them and the heights and

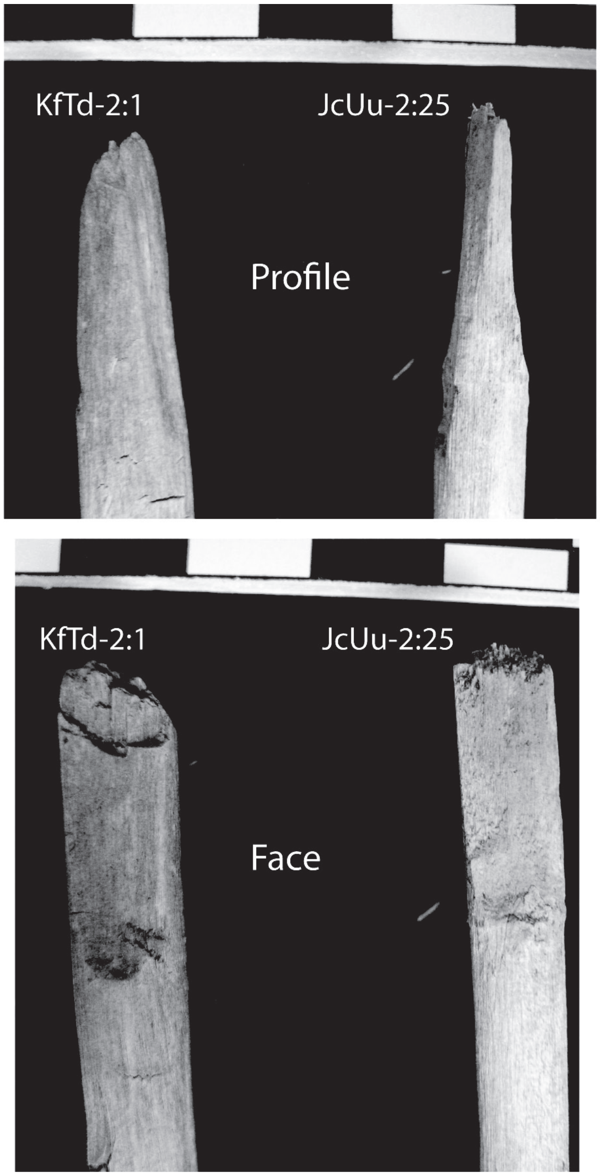

FIG. 10. Profiles and faces of bevel ends on birch arrow shafts. Scale bar in cm.

statures of the hunters who pulled the string. In cases where several shafts were found at one ice patch, similarities can be found between shafts that fall within a given time period, as is the case between JcUu-2:16 and 19 and JhVl-4:4 and 8 (Fig. 12). In these cases, we might be looking at arrows coming from the same quiver.

RADIOCARBON DATING THE ARROWS

The arrow shafts from the two ice patch regions mostly span the last 1000 years of hunting activities in the Subarctic, and early dates of ca. 850 ^{14}C years BP are found in both regions. Dates obtained on antler arrowheads from the southwestern Yukon ice patches are from the same time interval. As mentioned previously, there is one exception to this finding.

FIG. 11. Hemlock arrow shaft JcUu-2:17: detail of hafting type. Scale bar in cm.

JcUu-1:1 was reported on previously by Hare et al. (2004). It is an incomplete but long proximal fragment of birch shaft with a weathered proximal end showing a deep U notch (Fig. 13). It was dated twice to a consistent time period of 3510 ± 70 BP and 3600 ± 40 BP (Table 2). As discussed by Hare et al. (2004:268), this shaft fragment may represent an "early example of bow-and-arrow technology, apparently unrelated to the more widespread technology of the last millennium." However, with its distal end still missing, not much more can be said of this wooden shaft, and in view of its odd length and overall shape, its identification as an arrow shaft remains hypothetical.

In the Northwest Territories ice patches, the spruce arrow shaft is the oldest arrow, while the three birch arrow shafts span 300 radiocarbon years between 270 ± 40 ^{14}C BP (ca. 230 ± 230 cal BP) and 570 ± 40 ^{14}C BP (ca. 590 ± 70 cal BP). The dates of the two complete birch shafts with associated stone stemmed points overlap within two standard deviations between 465 and 301 cal BP. The complete shaft KhTe-2:1-6 overlaps entirely with the date of the willow bow found at an ice patch close to KhTe-2 (Fig. 14). The date of the small distal shaft fragment with a double bevel at its proximal end does not overlap with any of the other shafts but falls within a 100-year interval (651 – 521 cal BP) prior to the time interval of the other birch arrow shafts (Fig. 14).

In southwestern Yukon Territory, if one excludes the 3500-year-old shaft, the oldest shaft is made of pine (1010 ± 40 ^{14}C BP [ca. 930 ± 130 cal BP]). Both spruce and birch shafts are found in the 800 to 900 ^{14}C BP range and thus

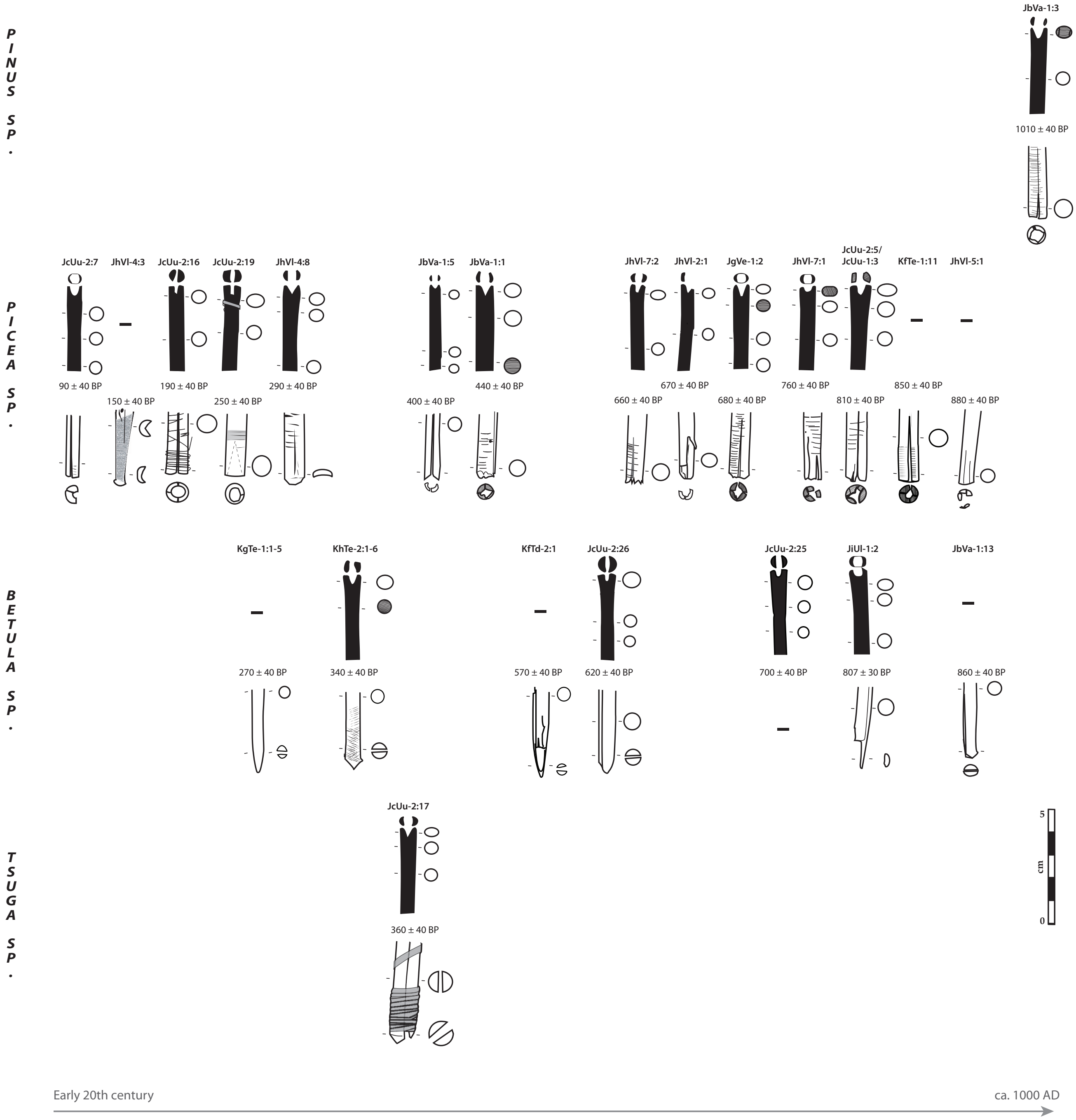

FIG. 12. Summary chart of arrow shaft nock and distal (hafting) ends from the two ice patch regions. (Drawing by C. Alix.)

are contemporaneous with the spruce arrow shaft from the Northwest Territories ice patch KfTe-1 (Fig. 14). Subsequently, the two main types of arrows date up to 275 cal BP, after which time all arrow shafts found so far are of spruce. The date of the single arrow shaft of hemlock falls within a 200-year interval between 510 and 310 cal BP (95.4%). As mentioned above, so far no correlation has been found between types of shafts, species of wood, and radiocarbon dates (Fig. 15).

In one case, a dating problem arose with a shaft that was dated twice to verify the first date obtained. JiUl-1:2 is a birch shaft that was found in 2009 and was first dated to 1720 ± 40 ^{14}C years old (Table 2). This date was largely outside of the range of dates that had been routinely obtained on arrow shafts from southwestern Yukon (Hare et al., 2004). The second time, the date was run in a different laboratory (Wk-28993) and came back as 807 ± 30 ^{14}C BP [720 ± 55 cal BP]. This new date is much more in line with the other dates on arrow shafts in both ice patch regions. We cannot explain why the two dates are so far apart, and only the second date is used in Figs. 12 and 15.

When taking the dates on all archery equipment from the ice patches of southwestern Yukon (antler arrow points and wooden arrow shafts, n = 36), there is a gap of 150

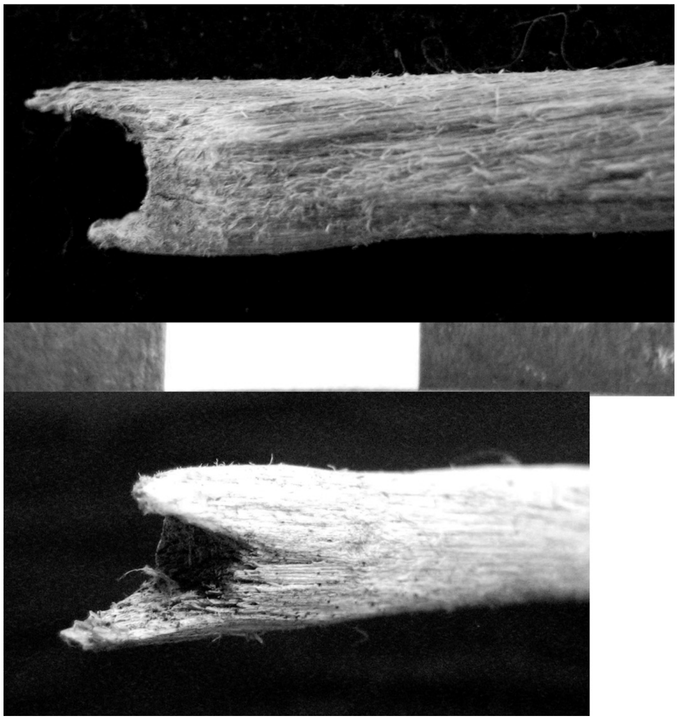

FIG. 13. Detail of nock end of oldest arrow shaft (JcUu-1:1). Scale bar in cm.

radiocarbon years between 440 ± 50 ^{14}C BP [490 ± 120 cal BP] and 590 ^{14}C BP [600 ± 70 cal BP], in an otherwise regularly spread series of radiocarbon dates. Once calibrated, the gap is less obvious, and the tail ends of the time range covered by the calibrated dates slightly overlap (Fig. 15). However, the fact remains that two sets of dates can still be clearly defined on each side of about 530 cal. BP as if around that time period the area had been less visited and used, or lost arrows had not preserved as well. Although the number of bow and arrow specimens is still low in the Selwyn Mountains, again one cannot but notice two sets of dates on each side of about 530 cal BP. It is hoped that continued research in both ice patch regions will provide a way to confirm the reality of what could be seen as a lesser use of the alpine ground in the early to mid 15th century, or alternatively, could be the result of taphonomy.

DISCUSSION

Discoveries of additional arrow shafts might make it possible in the future to link nock types to wood taxa and hafting types in a way similar to what is done with arrow shafts from ice patches in northern Norway (Farbregd, 2009). As of today, however, no clear chronological correlation can be made, although slight differences emerge within the three types (Fig. 12). The detailed analysis of 27 complete or nearly complete arrow shafts from two ice patch regions of western Subarctic Canada has led to identifying three main types of arrow shafts that are determined mainly by their wood taxa, their general shape and dimensions, and their hafting type.

1. Shafts of spruce (*Picea* sp.). These were made of very tightly grained, mostly knotless, and straight-grain white or black spruce. These shafts were hafted to shouldered or shoulderless and tanged antler arrowheads by way of a closed or open socket. These arrow shafts could also be made of pine, as shown by the shaft JbVa-1:3, which is, in many traits, similar to spruce arrow shafts. The length of the spruce arrow shafts ranges mostly between 52 and 63 cm. Incidentally, the two longest spruce arrow shafts (68 and 72 cm) are also the two most robust of the collection. The spruce and pine arrow shafts are barrel-shaped except for three shafts from the Alligator Lake ice patch JcUu-2, radiocarbon dated to the last 250 years.
2. Shafts of birch wood (*Betula* sp. cf. *B. neoalaskana*). These were made of the straight-grain, knotless wood of regularly grown Alaska paper birch trees. They were hafted to small stone arrow points by way of a simple split and tied with sinew lashing. Like most of the spruce shafts, these are barrel-shaped, but they are noticeably longer, ranging from 72 cm to more than 1 m in length. Comparatively and relative to their length, however, they have smaller diameters, and their balance point tends to be placed in the upper proximal half of the shaft rather than the lower distal half, as is the case for the spruce and pine arrows.
3. A shaft made of hemlock (*Tsuga* spp.). The unique specimen found so far is made of a straight-grain, knotless stave of hemlock. It was hafted to an antler arrowhead bearing a double-beveled tang by way of an extensive longitudinal split at the distal end of the shaft. It is rather long since the shaft itself measures over 73 cm, and unlike most spruce, pine, and birch shafts, it is tapered.

The presence of a hemlock arrow shaft made of a coastal wood species in a southwestern Yukon (interior) ice patch brings to mind the find of a hemlock wooden knife handle in an ice patch of northern British Columbia (Young, 2000b; Richards et al., 2007). This wooden handle is the only tool that was unequivocally associated with Kwäday Dän Ts'inchi, the 350- to 150-year-old body of a hunter found in an ice field of British Columbia (Beattie et al., 2000; Richards et al., 2007) at a location remarkably close geographically to the southwestern Yukon ice patches (Fig. 1). Kwäday Dän Ts'inchi was shown to have had a marine diet most of his life, but to have been traveling in the interior in the last days of his life (Richards et al., 2007). The hunter and his tool handle of hemlock are dated to a slightly later age interval (between AD 1670 and AD 1850; Richards et al., 2007:722) than the hemlock arrow shaft found in southwestern Yukon, which has a ^{14}C date calibrated to 1450 – 1635 cal AD [510 – 310 cal BP] (95.4%).

The presence of these hemlock objects, one with the body of a "coastal" hunter, at a significant distance from the coast supports the idea that the alpine hunting grounds of northern British Columbia and southwestern Yukon were visited, used, or traveled through by coastal hunters (see Richards et al., 2007:726 – 728) and thus by a wider diversity of people and cultural traditions than the local inhabitants. This diversity may explain some of the slight

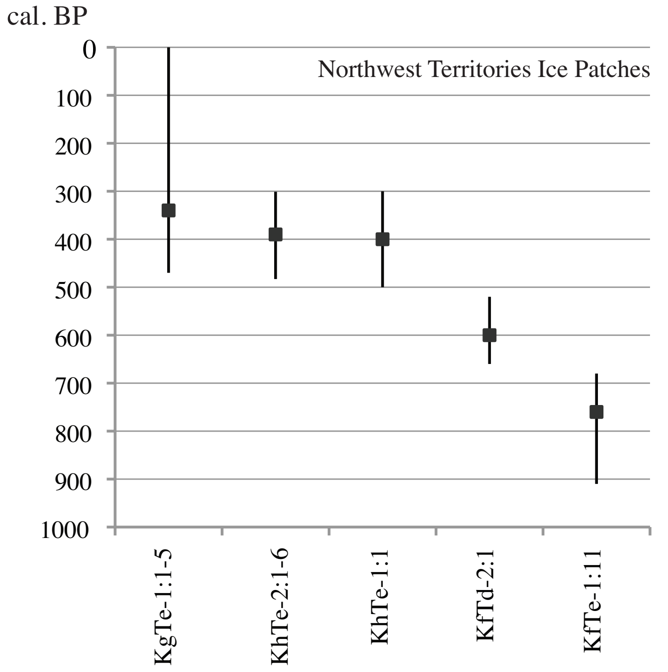

FIG. 14. Calibrated ^{14}C dates of all dated antler arrowheads and wooden arrow shafts from ice patches in the Northwest Territories. Black square is median calibrated age and bar is the calibrated 2σ range.

variations in the arrows found over the last thousand years (see Fig. 12). Interestingly however, to our knowledge none of the recorded oral history of British Columbia First Nations regarding types of wood used for making arrows mentions hemlock as a primary wood for arrow shafts (Table 1). However, among the Denai'na of south-central Alaska it is said that "hemlock wood is useful for anything that spruce wood is" (Russel Kari, 1995:36).

Birch and spruce arrows form two categories mounted with distinct types of arrowheads in terms of shape and raw material. They are present side by side during most of the last thousand years. When they are put side by side in chronological order, one difference appears in the make of the closed socket of the spruce arrow shafts (Fig. 12). From about 1000 ^{14}C years to 400 ^{14}C years ago, the closed socket is somewhat irregular, showing a cross-split of the wood as if the tang of the arrowhead had been forced into the wooden shaft. The more recent arrow shafts show a more regular closed socket that appears to have been shaped prior to hafting the arrowhead. Interestingly, it also in this more recent time interval that the open socket is found (Fig. 12).

Ethnographic accounts of Athapaskan First Nations of Canada and Alaska regularly report the use of birch and spruce in the making of arrow shafts and the use of primarily bone (but also stone, especially flint and slate) for making arrow points before the latter were replaced by metal (Mason, 1894; Osgood, 1936). Numerous accounts also describe the different types of arrows related to different game hunted. Distinctions are made repeatedly between arrows for large game or war, smaller game and birds, and yet smaller mammals. McKennan (1959), however, specifies that the Upper Tanana Native groups did not use stone for their arrows, the shafts of which were made of spruce. No mention has been found so far of birch shafts being hafted with stone points. According to these sources, the Han and Denai'na are reported as making their arrow shafts of birch as well as spruce (Table 1), but no particulars are provided regarding the use of one versus the other.

What is apparent from the collection of arrow shafts from the ice patch regions is that their shape and general outline within the two main types are relatively stable over the 1000-year period. They are, however, quite different from what is found outside of this interior Subarctic region, as was shown with the comparison of Arctic arrows. Variation within the general consistent types can reflect different shooting goals, different makers, or different Aboriginal groups; slight but significant changes may also appear over time, especially in the last 300 years (Fig. 12). Similar characteristics found on shafts that are contemporaneous within some of the richest ice patches (JcUu-2 and JhVl-4) tend to support the view that some arrows may have come from the same quiver. Mason (1894) reports how shafts in quivers tended to resemble each other and how arrows made by a given maker were easily recognizable. These similarities and differences observed on the 27 arrow shafts of the two ice patch regions may suggest that groups with different traditions of arrow shaft making or individuals with specific "trademarks" came to and possibly shared the alpine area of the Coast and the Selwyn Mountains to hunt caribou during the last 1000 years.

CONCLUSION

The detailed analysis of the assemblage of 27 arrow shafts has shown the presence of two main types of arrow shafts within the two ice patch regions plus a rare third type. The type differentiations are based on wood species, hafting and arrowheads, and balance point vs. length of the shaft. The discussion of the adequacy of specific wood types to become arrow shafts suggests that the main species used by the Subarctic hunters share more or less similar qualities (Table 3) and, given the mechanical values found for modern commercial wood, all rated very good to excellent. However, serviceberry (*Amelanchier* sp.) rated low even though Saskatoon berry (*Amelanchier alnifolia*) is known and has been recorded extensively as a remarkable arrow wood. This discrepancy raises the question of using the mechanical values of southern commercial wood to rate traditionally used Subarctic wood species and the need to test Subarctic wood bearing the characteristics described for arrow shafts.

The variation of forms, dimensions, wood types, nock end, hafting method, and arrow points in between the groups also shows the need for systematic and controlled ballistic and dynamic tests of these arrows. As much as possible, these experiments should be conducted in association with reconstructing the bows found in the ice patches.

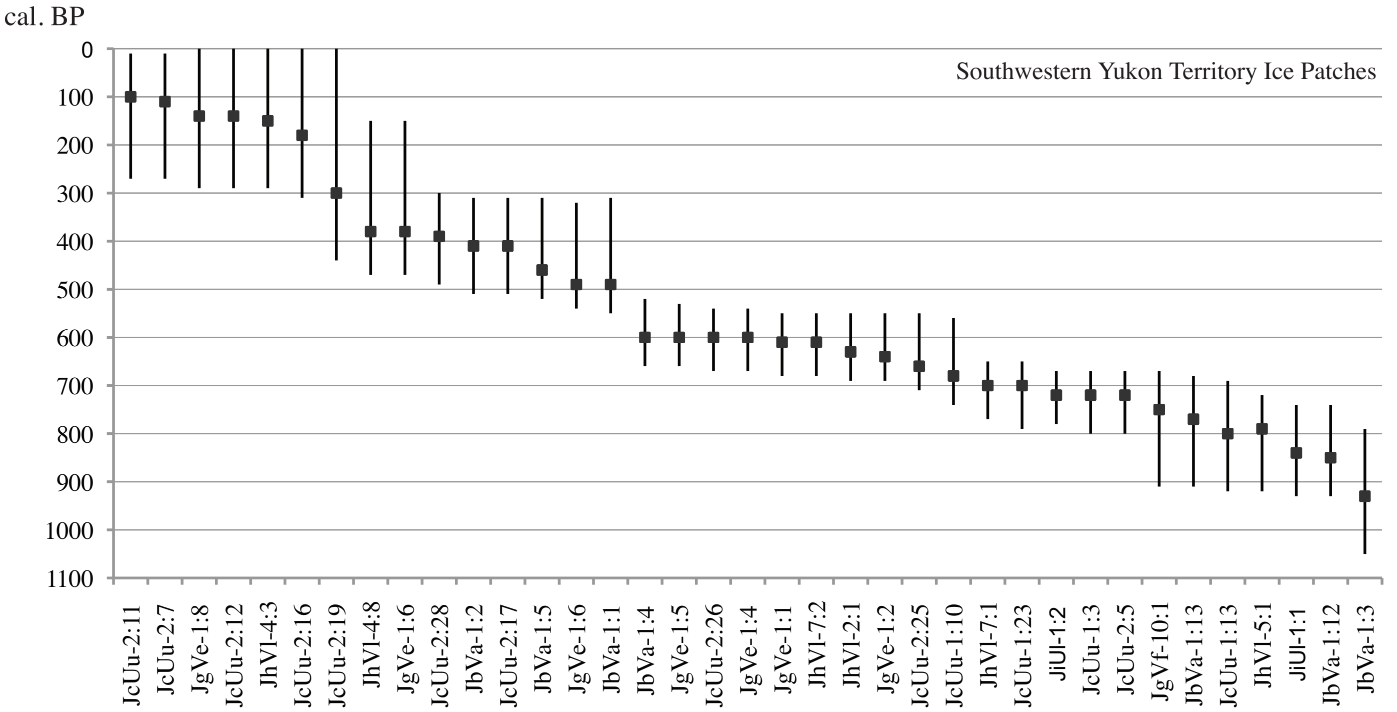

FIG. 15. Calibrated ^{14}C dates of all dated antler arrowheads and wooden arrow shafts from ice patches in the southwestern Yukon. Black square is median calibrated age and bar is the calibrated 2σ range.

It may also be possible that the different types of arrows correspond to different types of bows, as bows are also known to bear strong cultural characteristics.

Continued descriptions of arrow shafts from ice patches and other frozen contexts and future research will refine the chronology. Eventually, these data will provide a typo-chronology of the arrow shafts in the region and a clearer understanding of bow-and-arrow technology in the Western Subarctic.

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