ARCTIC
VOL. 65, SUPPL. 1 (2012) P. 1–21

Archaeological Investigations of Alpine Ice Patches in the Selwyn Mountains, Northwest Territories, Canada

THOMAS D. ANDREWS,[1,2] GLEN MacKAY[1] and LEON ANDREW[3]

(Received 22 February 2011; accepted in revised form 21 March 2011)

ABSTRACT. Inspired by the groundbreaking investigation of ice patch archaeology in Yukon Territory, the authors began exploring the Mackenzie, Selwyn, and Richardson Mountains for ice patch archaeological sites in 2000. Through remote sensing analysis, followed by intensive field surveys in the Selwyn and Mackenzie Mountains, we documented eight ice patch sites containing well-preserved archaeological artifacts and biological specimens. Twenty additional ice patches exhibit the key indicators of ice patch archaeological sites (permanent or intermittent ice and snow lenses containing caribou fecal matter, faunal material, or both), but so far these patches have not yielded artifacts. Collections from ice patches in the Selwyn Mountains include examples of three precontact hunting technologies: throwing dart (atlatl), bow-and-arrow, and snare. Atlatl technology, represented by the distal ends of two darts dating to 2410 and 2310 ^{14}C yr BP, predates bow-and-arrow technology, represented by two complete arrows, two distal shaft fragments, and a partial bow dating between 850 and 270 ^{14}C yr BP. A ground squirrel snare dates to 970 ^{14}C yr BP. Caribou dominates the faunal remains recovered from the ice patches. These data suggest that hunting on ice patches was part of a broader-spectrum summer subsistence economy focused on a broad alpine valley, known locally as K'atieh, and that hunters tended to target ice patches close to other subsistence locations in this area.

Key words: ice patch archaeology, mountain woodland caribou, Selwyn Mountains, dart-throwing technology, bow and arrow, ground squirrel snare

RÉSUMÉ. Inspiré par les travaux révolutionnaires de l'archéologie des névés menés dans le territoire du Yukon, les auteurs ont commencé en l'an 2000 l'exploration des montagnes du Mackenzie, de Selwyn et de Richardson afin d'y trouver des sites archéologiques associés à des névés. L'analyse des données de la télédétection suivie d'un programme de prospection intensif dans les montagnes de Selwyn et du Mackenzie a permis de documenter huit sites de névés qui contiennent des objets archéologiques et des spécimens biologiques bien conservés. Vingt autres sites présentent les caractéristiques des sites archéologiques de névés (soit des lentilles de glace et de neige permanentes ou semi-permanentes contenant des matières fécales et (ou) de la faune), mais n'ont livré pour l'instant aucun artefact. Les collections des névés des montagnes Selwyn comprennent des exemplaires de trois systèmes d'armes de chasse antérieures au contact. La technique du tir au propulseur est représentée par les extrémités distales de deux lances datant de 2410 et 2310 années radiocarbones BP et est antérieure à celle de l'arc et de la flèche qui consiste en deux flèches complètes, deux fragments distaux de hampe et un arc incomplet datés entre 850 et 270 années radiocarbones BP. Un piège à spermophile date de 970 années radiocarbones BP. Les ossements de caribou dominent les restes de faune trouvés dans les névés. Ces données laissent entendre que la chasse dans les zones alpines faisait partie d'une économie de subsistance estivale dans laquelle un large éventail d'espèces était chassé. Ces activités de subsistance se concentraient dans les larges vallées alpines, connues localement sous le nom de K'atieh et les chasseurs avaient tendance à cibler les névés localisés à proximité des autres ressources de la région.

Mots clés : archéologie des névés, caribous des bois des montagnes, chaîne de Selwyn, utilisation de propulseurs, arcs et flèches, piège à écureuil terrestre

Révisé pour la revue Arctic par Nicole Giguère.

INTRODUCTION

Prompted by the discovery and initial characterization of ice patch archaeological sites in Yukon Territory (Kuzyk et al., 1999; Farnell et al., 2004; Hare et al., 2004), recent work in other alpine regions of North America has expanded the archaeological record of alpine ice patches to include interior Alaska (Dixon et al., 2005; VanderHoek et al., 2007a, b, 2012), the northern Rocky Mountains of the continental United States (Lee, 2012), and, as reported in this paper, the Selwyn Mountains of the Northwest Territories. Parallel efforts in the alpine regions of Norway, where ice patch archaeology has a long history (Farbregd, 2009; Callanan, 2010, 2012), and in Switzerland (Grosjean et al.,

[1] Prince of Wales Northern Heritage Centre, PO Box 1320, Yellowknife, Northwest Territories X1A 2L9, Canada
[2] Corresponding author: tom_andrews@gov.nt.ca
[3] PO Box 475, Norman Wells, Northwest Territories X0E 0G0, Canada

2007; Hafner, 2012) extend the geographic scope of these studies to a hemispheric scale.

Caribou and wild reindeer seek relief from warm summer temperatures and insect harassment on alpine ice patches (Ion and Kershaw, 1989; Anderson and Nilssen, 1998). The emerging archaeological record of ice patches shows that hunters in these circumpolar study areas took advantage of this predictable behaviour to intercept and harvest caribou on these features (Hare et al., 2004; Dixon et al., 2005; VanderHoek et al., 2007b). Ice patches preserve a long-term record of this relationship: as annual net accumulations of winter snow were gradually compressed into permanent ice lenses, ancient remains of caribou (primarily dung deposited on the patch) and hunting weapons lost or discarded by precontact hunters were incorporated and preserved within the ice. These features preserve even the most fragile organic components of hunting artifacts over impressive time spans; Hare et al. (2004), for example, report on an assemblage from the Yukon Territory that spans almost the entire Holocene (from 8360 ± 60 to 90 ± 40 ^{14}C yr BP, or from ca. 9330 ± 190 to 40 ± 130 cal. yr BP).

Over the past decade, recognizing that changing climate regimes may place ice patches at risk, archaeologists in North America have put considerable effort into finding ice patch archaeological sites and collecting and conserving the fragile biological specimens and artifacts melting out of the ice. Finding ice patch archaeological sites in large tracts of remote alpine terrain has proven challenging, and thus researchers have applied such techniques as remote sensing (Dixon et al., 2005; VanderHoek et al., 2007b; Lee, 2012) and predictive modeling (Dixon et al., 2005) to focus their field surveys. Intensive field surveys have located numerous ice patch archaeological sites in the Yukon, Alaska, the Northwest Territories, and the northern Rocky Mountains of the continental United States. Regular monitoring of these sites is helping to ensure that well-preserved organic artifacts that have melted out of the ice are collected before their fragile organic parts—which often include wood, bone, antler, sinew, and feather components—begin to degrade.

In recent years, the data gathered through these efforts are beginning to inform a diverse set of research objectives. Large assemblages of hunting weapons have helped to refine culture-historical sequences and the timing of technological transitions (Hare et al., 2004; Farbregd, 2009). For example, Hare et al. (2004) were able to pinpoint the abrupt transition from throwing-dart technology to bow-and-arrow technology in northwestern North America by directly dating the organic components of artifacts collected from Yukon ice patches. In addition, typological and technological analyses of complete projectiles are shedding light on the design of precontact weapon systems (Alix et al., 2012; Hare et al., 2012), and other studies are generating information on materials such as the feathers and adhesives used in projectile weaponry (Dove et al., 2005; Helwig et al., 2008). Recent research has also focused on situating ice patch hunting into a broader context of precontact land use (Hare et al., 2004; VanderHoek et al., 2007b; Greer and Strand, 2012). In some cases, this work is drawing on the traditional knowledge of Aboriginal Elders as an important source of information on traditional land-use patterns (Andrews et al., 2012; Greer and Strand, 2012). Continuity and change in these patterns of land use are being evaluated against an increasingly detailed paleoenvironmental record of the alpine landscape (see Hare et al., 2012), as the biological specimens preserved by alpine ice patches provide rich material for reconstructing long-term trends in vegetation and caribou diet (Farnell et al., 2004; Galloway et al., 2012), the long-term dynamics of caribou populations (Kuhn et al., 2010; Letts et al., 2012), and patterns of ice patch growth and ablation (Farnell et al., 2004; Meulendyk et al., 2012).

In this article, we report on the results of our efforts to find and characterize ice patch archaeological sites in the Selwyn and Mackenzie Mountains of the Northwest Territories and discuss the importance of these results for understanding precontact adaptations to the high alpine environment of this region. Figure 1 shows the study area for the project, which consists of the alpine regions of the Tulita District of the Sahtu Settlement Area and falls within the traditional land-use area of the Shúhtagot'ine or Mountain Dene (see Andrews et al., 2012, for a description of the Shúhtagot'ine).

Overview of the Ecology and Culture History of the Study Area

The study area falls within the physiographic region of the Selwyn Mountain complex, a northern extension of the Western Cordillera. The Selwyn and Mackenzie Mountains, along with the Ogilvie and Richardson Mountains to the northwest, form the continental divide, and our study area therefore lies in the lee of the predominant westerly airflow. The study area also falls within the southern portion of the Taiga Cordillera Ecozone, which is a diverse area of mountain ranges rising to heights of over 2700 m above sea level (asl), glaciers, mineral springs, rolling hills, high plateaus, broad depressions, and incised valleys. The bedrock geology is predominantly Paleozoic sedimentary rock, with large segments of Precambrian and Mesozoic intrusives (NWT Geoscience Office, 2009).

The region's cold continental climate is characterized by wide monthly variations in temperature and precipitation: maximum and minimum temperatures recorded at Norman Wells (located 287 km NE of ice patch archaeological site KfTe-1; see Fig. 1) are 35˚C and -54.4˚C, respectively (Environment Canada, 2011). From June to August, the mean maximum and minimum temperatures at Tungsten (located 126 km south of KfTe-1) are 17˚C and 6˚C; the absolute maximum and minimum for these months are 30˚C and 0˚C. Average monthly precipitation from June to August is 60 to 90 mm, with severe thunderstorms occurring in July. Temperatures decrease and precipitation tends to increase with elevation, and snow may fall at any time of the year.

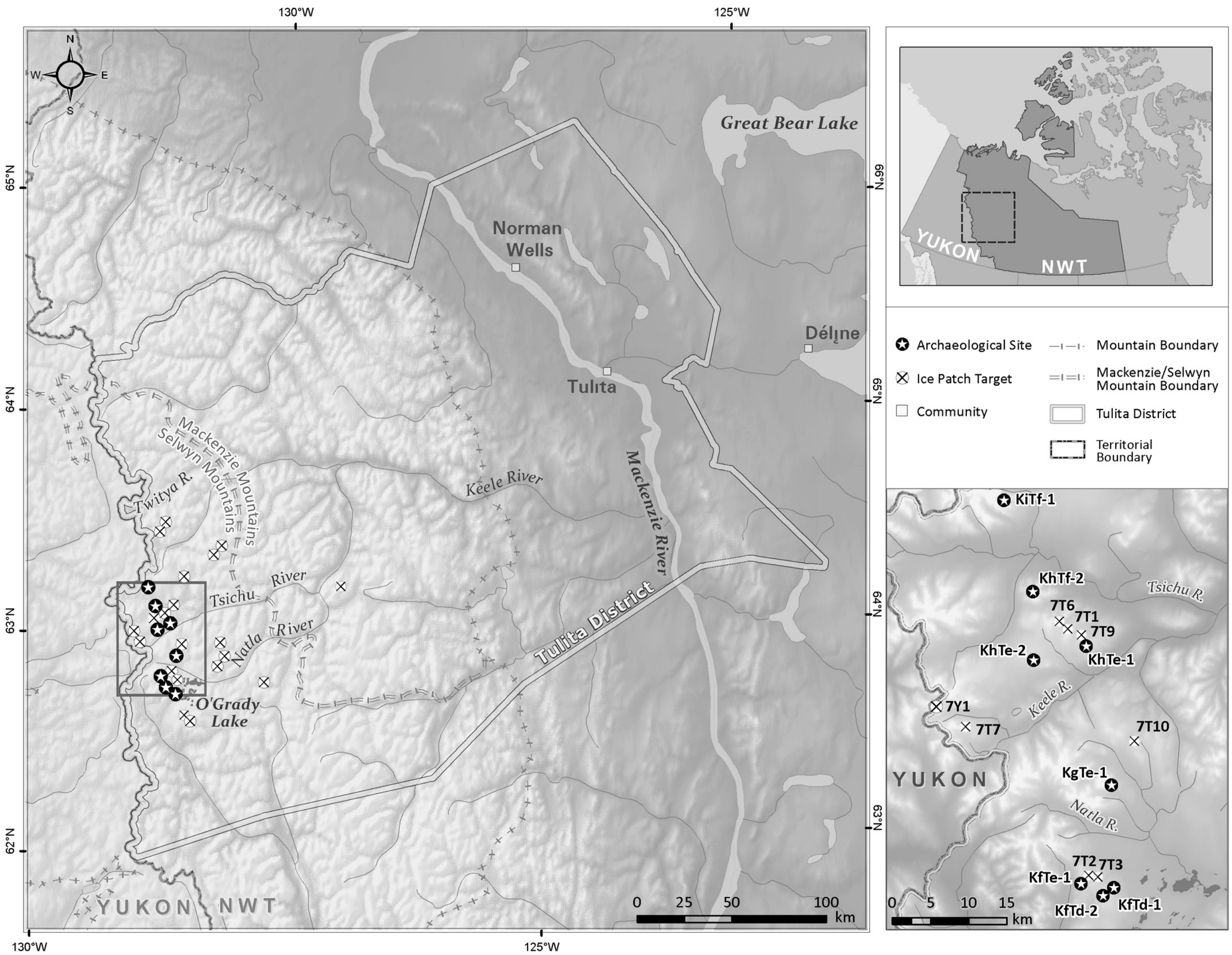

FIG. 1. An overview map showing the study area and significant places mentioned in the text.

Annual fluctuations in snowfall and temperature can affect the summer configuration of ice patches.

The study area contains vegetation types of two major biomes: boreal forest and alpine tundra. Moving west from the Mackenzie River toward the continental divide, the elevation difference between valley bottoms and mountain tops decreases. Therefore, valley bottoms in the eastern portion of the study area are characterized by all stages of boreal forest, from recent burns to mature spruce forests, grading to alpine tundra on the mountain slopes. Densely growing white spruce (*Picea glauca*) and poplar (*Populus* sp.) dominate these valley bottoms. At higher altitudes and on the northern slopes, black spruce (*Picea mariana*) is more prominent. Alpine tundra, characterized by sedges, lichens, grasses, and shrubs, occurs on the higher mountains. The higher-elevation valleys in the western part of the study area, near the ice patch locations, are commonly dominated by birch tundra (Pojar, 1966).

The upper Natla River valley area, located east of O'Grady Lake (13 km east of KfTe-1), has been described as exhibiting five vegetation zones: spruce forest, forest-tundra, birch tundra, herb tundra, and bare rock with scattered herbs and lichens (MacDonald, 1983). The spruce forest zone, usually restricted to elevations below 1350 m asl, is dominated by white spruce, though black spruce dominates on poorly drained sites. As elevation increases, spruce gives way to a vast birch tundra dominated by dwarf birch (*Betula glandulosa*). Reindeer moss (*Cladonia* spp.), sedges (*Carex* spp.), and *Sphagnum* bogs are common in this area and in the interface with the spruce forest zone. At higher elevations, birch gives way to willow (*Salix* sp.) and herbs. High elevations and steep slopes comprise bare rock or regolith, with scattered crustose lichens and herbs (MacDonald, 1983).

The diverse wildlife of the study area includes more than 40 species of mammals, among which are beaver (*Castor canadensis*), grey wolf (*Canis lupus*), grizzly bear (*Ursus arctos*), black bear (*U. americanus*), otter (*Lutra canadensis*), wolverine (*Gulo gulo*), lynx (*Lynx canadensis*), woodland caribou (*Rangifer tarandus caribou*), moose (*Alces

alces), mountain goat (*Oreamnos americanus*), Dall sheep (*Ovis dalli*), and a wide range of rodents, including marmot (*Marmota caligata*) and ground squirrel (*Spermophilus parryii*). Over 175 species of birds from 29 families are known, including peregrine falcon (*Falco peregrinus anatum*), golden eagle (*Aguila chrysaetos*) and bald eagle (*Haliaeetus leucocephalus*). There are no known reptiles and few amphibians. Sixteen species of fish are known, including Arctic grayling (*Thymallus arcticus*), Dolly Varden trout (*Salvelinus malma*), northern pike (*Esox lucius*), lake (humpback) whitefish (*Coregonus clupeaformis*), and lake trout (*Salvelinus namaycush*), all of which are important for local subsistence.

The Shúhtagot'ine (Mountain Dene) are the traditional inhabitants of the Selwyn and Mackenzie Mountains (Gillespie, 1981). In historic times, while spending winters in the lower mountain valleys, primarily along the Mountain, Keele, Redstone, Dahadinni, and Root Rivers, the Shúhtagot'ine would set nets through the ice for fish; take small game using a variety of snares, nets, and rifles; and hunt sheep, caribou, and moose, using snares, fences, and rifles. By staying at lower altitudes, they avoided the high winds and deep snow near the continental divide and were able to take advantage of large game that moved to lower elevations for the same reasons. In spring they would travel to posts on the Mackenzie River in the Northwest Territories or on tributaries of the Peel and Yukon Rivers in the Yukon to trade, and they would often stay nearby for the summer, spending their time fishing. In late summer, the Shúhtagot'ine would begin to walk back into the mountains following well-defined trails, ready to spend the winter again. Shúhtagot'ine oral tradition talks of hunting on ice patches primarily in summer, when caribou began to seek these higher elevations to escape the warming days (see Andrews et al., 2012).

Ice Patches and Caribou in the Selwyn and Mackenzie Mountains

Permanent ice patches are ice bodies that form on leeward slopes at high elevations in alpine regions (Farnell et al., 2004; Meulendyk et al., 2012). The presence of a permanent ice core distinguishes these features from late-lying snow patches and intermittent ice patches, which tend to melt away during warm summers. Permanent ice patches are often thousands of years old; for example, accelerator mass spectrometry (AMS) dates on caribou dung extracted from ice patch KiTf-1 in the Selwyn Mountains indicates that this feature predates 4580 ± 40 ^{14}C yr BP (ca. 5250 ± 200 cal. yr BP). While ice patches can be more than a kilometer long and several meters thick, they differ from glaciers in that they do not acquire enough mass to flow downslope.

An important feature that ice patches share with glaciers is that they accumulate through precipitation. The developmental model for ice patch formation outlined by Meulendyk et al. (2012) demonstrates that ice patches begin as snowdrifts that accumulate on leeward alpine slopes during the winter. Ice patches KfTe-1 and KhTe-2 in the Selwyn Mountains, for example, are located on slopes facing north to northeast in an area with prevailing southwest winds. This north-facing aspect protects the accumulated snow from summer insolation, allowing snowdrifts to survive through the summer months, particularly in years of high winter precipitation and cool summer temperatures. Over time, densification of snow and firn lead to the formation of an ice body. Nivation processes initiated by the late-lying snowdrifts and incipient ice cores create hollows that support further accumulation of snow, thus promoting increased ice patch growth (Farnell et al., 2004; Vanderhoek et al., 2007b; Meulendyk et al., 2012). In this manner, snow and ice tend to accumulate in a consistent location over time.

In concert with the winter accumulation of snow, deposition of caribou dung also influences the internal structure of ice patches. Ice patch KfTe-1, for example, has between three and seven distinct ice bodies separated by continuous layers of dung (Meulendyk et al., 2012); consequently, actively melting ice patches tend to be ringed by a distinct black band consisting of caribou dung (Fig. 2).

A recent study of mitochondrial DNA sequences extracted from ancient bones collected at ice patches in the Selwyn Mountains indicates that the caribou responsible for these dung layers belong to the Redstone population (Letts et al., 2012). The Redstone caribou are woodland caribou of the northern mountain ecotype. In contrast to woodland caribou of the boreal ecotype, which live the entire year in the boreal forest, mountain ecotype caribou spend winter at lower elevations and migrate to higher elevations, characterized by alpine tundra, in the summer (Creighton, 2006). Caribou of the Redstone population, which may number as many as 5000 to 10 000 animals, typically winter in the river valleys of the front ranges of the Mackenzie Mountains and tend to migrate to alpine habitat near the continental divide for the summer months (Creighton, 2006). Ice patches play an important role as relief habitat on this summer range.

Like windswept mountain ridges or barren coastal expanses, the cool microclimates of late-lying snowdrifts and ice patches are important to caribou for relief from insect harassment and thermoregulation (Ion and Kershaw, 1989; Anderson and Nilssen, 1998). Observations by Ion and Kershaw (1989) in the Selwyn and Mackenzie Mountains indicate that caribou tend to migrate to snow and ice patches on days with relatively high air temperatures and low wind speeds. On these days, caribou move from valleys to snow patches and ridges at higher elevations in the late morning and descend in the late afternoon or evening. Snow distribution data recorded by Ion and Kershaw (1989) show that the extent of summer snow available to caribou dwindles markedly over the summer. Focusing on an area of 50.7 km^2 in the Selwyn and Mackenzie Mountains, they found that snow covered 53% of the study area in early June. By mid-August, however, only 0.9% of the

FIG. 2. Ice patch archaeological site (KhTe-2) in 2009, showing dung band and numerous caribou trails.

study area was covered in snow, and this snow was confined to 30 snow or ice patches at elevations above 1750 m asl. Late summer air photos taken in 1945, 1949, and 1974, as well as field observations, indicate that some of these patches either recurred or remained in the same locations over many years (Ion and Kershaw, 1989). Taken together, these data show that the movement of caribou to snow and ice patches is a predictable behaviour under certain weather conditions, and that by late summer relatively few snow-covered areas are available for caribou relief habitat. These remaining areas tend to be found in the same locations from year to year.

RESEARCH METHODS: FINDING ICE PATCH ARCHAEOLOGICAL SITES IN THE NORTHWEST TERRITORIES

Faced with finding ice patch archaeological sites in a remote mountainous area of nearly 144 000 square kilometers, we drew on the experience of Yukon archaeologists to help us define areas with greater potential to contain productive ice patches. We established six defining criteria: (1) presence of multi-year ice; (2) presence of extensive amounts of caribou dung (Such areas are characterized by a black edge on the downslope side of the ice patch, where the ice patch is actively melting. The black band is most visible between the first and last weeks of August, when most melting takes place.); (3) location at 1676 – 1981 m (5500 – 6500 ft) asl (at 61˚N); (4) location on north-facing side of mountains; (5) bowl or cirque shape of ice patch outline; and (6) distance of 10 – 15 km from a subsistence location, particularly a fish lake.

We gathered several spatial datasets to model these criteria and compiled this information in ArcGIS to build a tool for identifying areas with potential to contain ice patch archaeological sites.

Remote Sensing

We used remote sensing technology to assess the presence of multi-year ice in the alpine regions of the Northwest Territories. With the assistance of remote sensing analysts at the NWT Centre for Geomatics, we acquired Landsat 7 imagery and developed an image analysis protocol designed to identify multiyear ice. We used Landsat 7 imagery taken in the month of August to approximate the time of maximum summer melt. For the image analysis, raw images were geo-corrected and analyzed using a modified Normalized Difference Snow Index (NDSI) to automate the initial mapping of snow or ice patches. NDSI is a ratio transformation using bands 5 and 2, which converts digital numbers to reflectance values to calculate the index:

$$\text{NDSI} \frac{(\text{band 2 reflectance - band 5 reflectance})}{(\text{band 2 reflectance + band 5 reflectance})}$$

Resulting index values above 0.35 were classified and mapped as ice or snow polygons. Thresholding on bands 2 and 4 was used to remove misclassified elements such as narrow river courses, lakes, and shadows. Finally, we used Canadian digital elevation data (CDED) at a scale of 1:250 000 to remove snow and ice pixels at elevations of less than 914 m (3000 ft) from further analysis.

Landsat 7 imagery analysis was conducted in two phases. The goal of the first phase was to select a sub-area of the mountains on which to focus a more intensive assessment of ice patch potential. Focusing on the criterion that ice patch archaeological sites tend to be located near subsistence locations such as fish lakes, we chose three traditional fish lakes at three different latitudes—Fisherman Lake (60˚20′ N, 123˚45′ W), Wrigley (Drum) Lake (63˚51′ N, 126˚10′ W), and Canoe Lake (68˚13′ N, 135˚15′ W)—and acquired Landsat 7 imagery for the alpine terrain near each of these locations. All three locations are well known locally as subsistence fish lakes and have been the subject of some previous archaeological research.

This first phase of image analysis revealed little evidence of multiyear ice patches in the Fisherman Lake and Canoe Lake study areas, leading us to drop these areas from further analysis. Elevations in both of these areas are at the extreme lower end of the range for archaeological ice patch occurrence in the Yukon. Thus, we chose to focus our efforts on the Drum Lake study area. In the second phase of imagery analysis, we broadened the study area to include all of the alpine regions of the Tulita District (see Fig. 1). All subsequent analyses described in this section focused on this broader study area.

Satellite imagery contained in virtual globes provided an additional remote sensing tool (see Lee, 2012). Google Earth proved useful because the 15 m TrueEarth imagery base it employs included images of our study area captured in August, providing us with a tool for identifying potential targets to examine during fieldwork. However, Google Earth's practice of updating imagery on a regular basis sometimes meant that useful summer imagery was replaced with higher-resolution winter imagery that was less useful for our purposes. ArcGIS Explorer includes imagery (likely i-cubed 15 m eSAT imagery) that is similar to the TrueEarth base used in Google Earth prior to these updates.

Finally, we examined aerial photography at Canada's National Air Photo Library in Ottawa. Although hundreds of reels of film have been taken over the study area, only a small percentage of this footage was shot during the late summer, limiting the actual number of useful images to only a few dozen.

Modeling Other Criteria

As our analysis of the Landsat 7 imagery indicated that late-lying snow and ice were widespread in the Selwyn and Mackenzie Mountains, we compiled several additional spatial datasets to determine which of these ice patches were most likely to contain archaeological materials. Basing our analysis on the general characteristics of ice patch archaeological sites identified by Yukon archaeologists and listed above, we included spatial data on caribou movement patterns, traditional land use, and elevation.

In light of the limited ability of Landsat 7 imagery to detect deposits of caribou dung at the perimeters of ice patches, we used location data from satellite-collared caribou to assess the use of ice patches as relief habitat by modern caribou in the Selwyn and Mackenzie Mountains. These data were gathered from 10 adult female caribou of the Redstone population collared with Telonics ST-10 satellite collars (see Creighton, 2006 for a description of the data collection process). The animals were collared in March 2002 by biologists from the Government of the Northwest Territories Department of Environment and Natural Resources and the Sahtu Renewable Resources Board as part of a study to obtain information on the seasonal range, movement patterns, seasonal habitat use, and routes and timing of seasonal migrations of the Redstone population (Creighton, 2006). The Sahtu Renewable Resources Board provided our project with a dataset of daily caribou locations from 30 May 2002 to 30 March 2005. We edited these data by deleting positions with a location quality score of 0 or 1 (Creighton, 2006; Weaver, 2006). Following Creighton (2006), we also deleted several erroneous records and positions recorded from stationary collars, i.e., data from released collars or collars transmitting from dead animals. To approximate the time period when caribou were most likely to seek relief from insect activity and warm summer temperatures on ice patches, we mapped caribou locations for the months of June, July, and August. While these data are limited to the extent that they represent a small sample size and do not track the movements of males, the results of a recent mitochondrial DNA study showing genetic continuity of the Redstone caribou population over several millennia provides some confidence that these data reflect ancient movement patterns (see Letts et al., 2012).

As it has been well established in the Northwest Territories that traditional land-use data are particularly useful for archaeological surveys and site interpretation (Hanks and Winter, 1986; Andrews and Zoe, 1997; Hanks, 1997), we used traditional trail data to assess the traditional land-use patterns of the Shúhtagot'ine. The trail data were collected by the Dene Mapping Project in the late 1970s and early 1980s and augmented by our own traditional knowledge research (see Andrews et al., 2012). These data record the trails traveled by Dene hunters and trappers over their lifetimes, providing a good approximation of traditional land use in the Selwyn and Mackenzie Mountains.

Finally, acting on the observation of Yukon archaeologists that most ice patch archaeological sites are typically found at elevations above 1524 m (5000 ft.), we applied a digital elevation model (DEM) to our study area to "flood" the mountains to this elevation. The simulated flood made it easy for us to identify higher-potential terrain for further analysis, while eliminating vast areas of expected low productivity.

Field Survey

Intensive field surveys were conducted over five field seasons (2005 and 2007 – 10) to examine areas of high potential for ice patch archaeological sites identified by our modeling efforts, and, as the project progressed, to monitor confirmed ice patch targets annually. Potential sites were inspected during the second or third week of August (the time of maximum melt).

RESULTS

Remote Sensing and Modeling the Location of Ice Patch Archaeological Sites

While the limited resolution of Landsat 7 imagery made the identification of caribou dung bands problematic, our image analysis protocol was successful in identifying late-lying snow and ice in the Selwyn and Mackenzie mountains (cf. Dixon et al., 2005; VanderHoek et al., 2007b). In general, the Landsat 7 imagery analysis showed that late-lying snow and ice were widespread in our study area, but that the density of snow and ice patches increased westwards towards the continental divide (marked approximately by the Northwest Territiories-Yukon border). Interestingly, the 15 m TrueEarth imagery employed by Google Earth was able to discern several ice patches in the high alpine area near the continental divide that were ringed by a black band, resulting in the identification of specific targets for our field survey. Similarly, aerial photograph analysis resulted in the identification of one ice patch with a visible dung band (ice patch archaeological site KhTe-1), but ultimately the usefulness of this approach was limited by the general lack of air photos of our study area captured during the summer months.

In short, the results of the imagery analysis indicated that the high alpine areas adjacent to the continental divide contained abundant late-lying snow and ice and

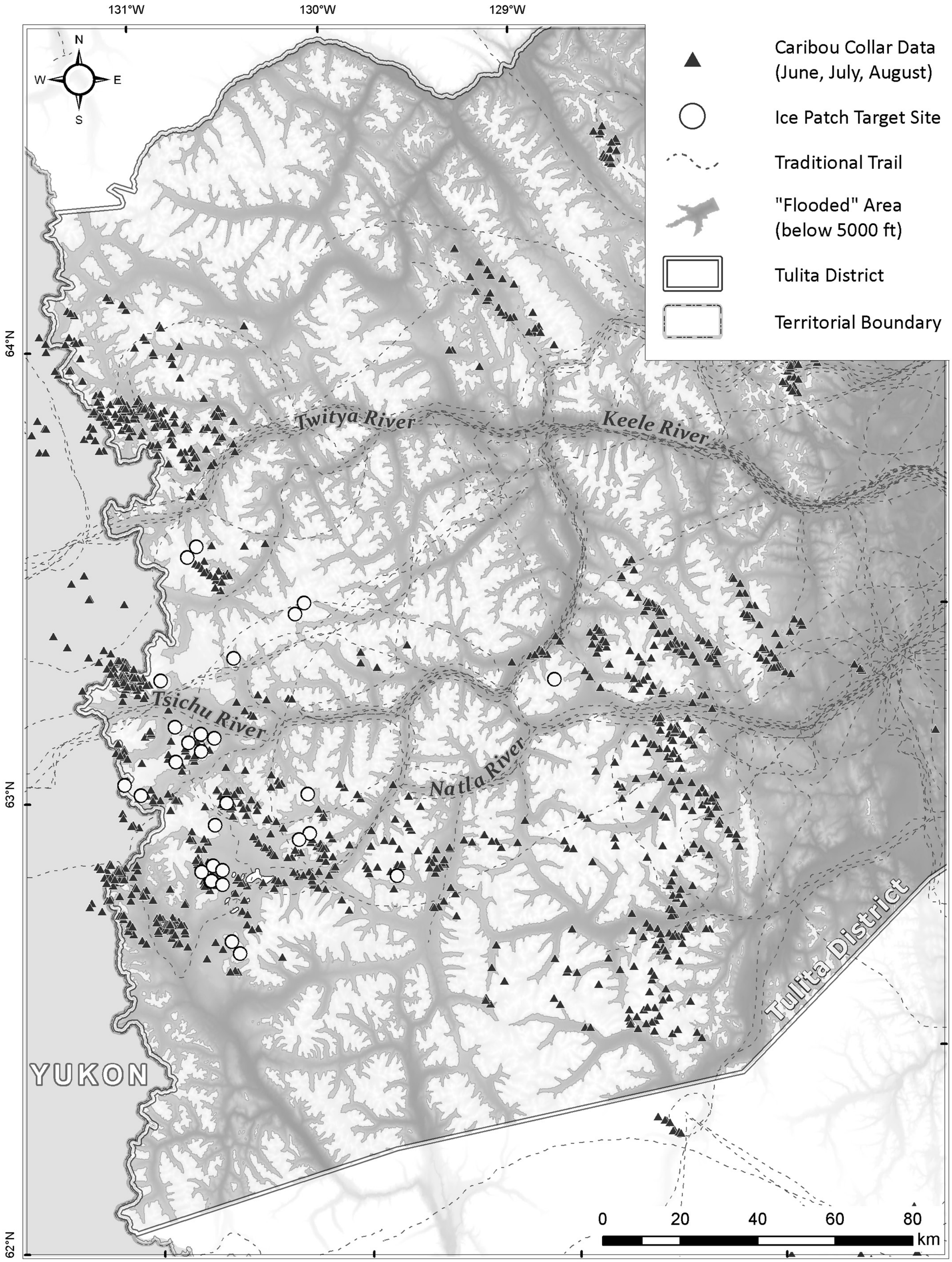

FIG. 3. A map of the study area showing the positions of satellite-collared caribou, ice patch target sites, traditional trails, and areas "flooded" to an elevation of 1524 m (5000 ft.) asl.

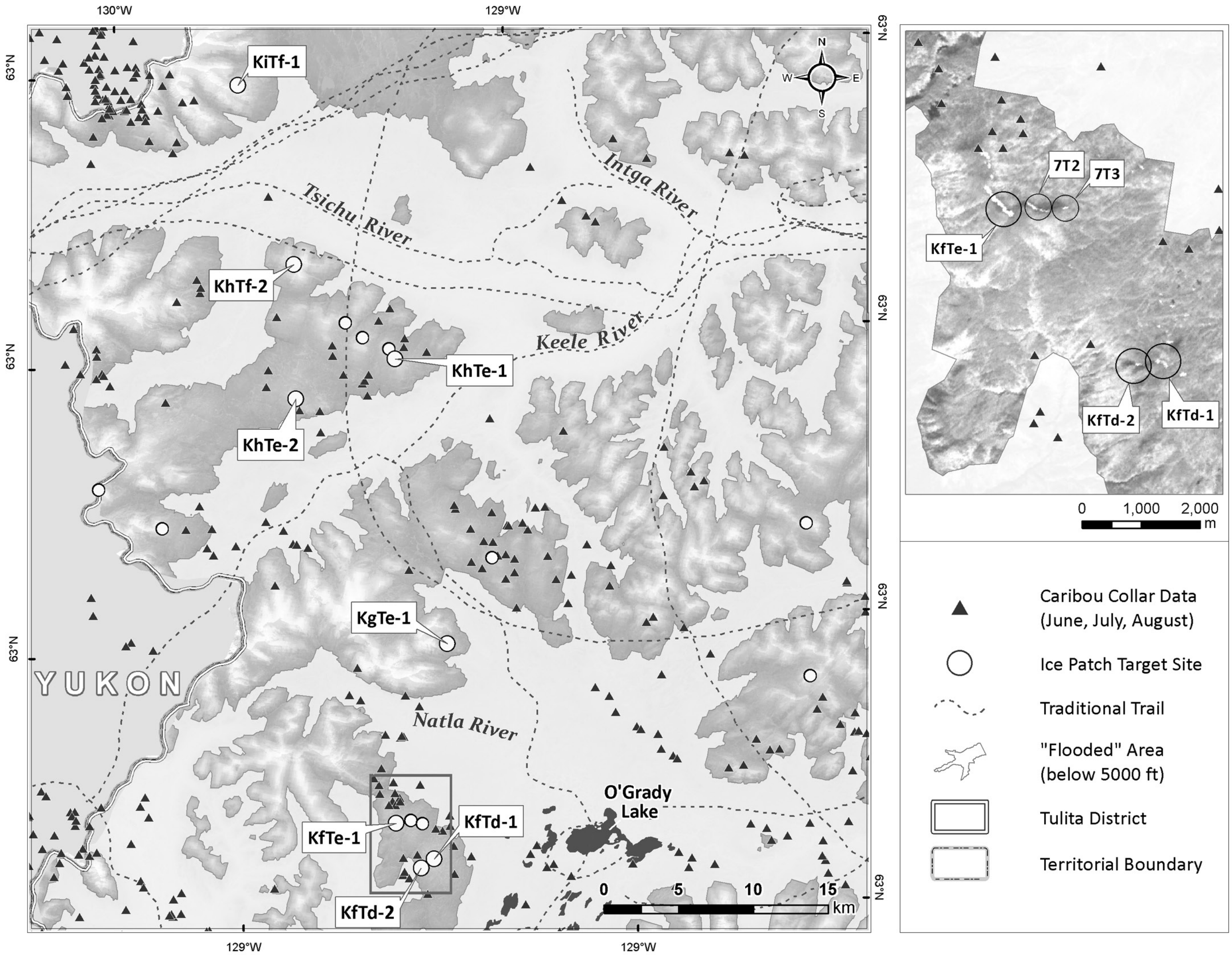

FIG. 4. A view of all eight ice patch archaeological sites, showing details of caribou satellite collar positions, traditional trails, and areas “flooded” to 1524 m (5000 ft.) asl.

provided some evidence that caribou used these features. Modeling modern caribou movements, traditional land use, and elevation resulted in further delineation of areas expected to have greater potential for ice patch archaeological sites. Figures 3 and 4 show the caribou collar and traditional trail data mapped at different scales. In these maps, the valleys have been “flooded” to an elevation of 1524 m (5000 ft.). These figures indicate several broad areas where summer caribou positions intersect with elevations above 1524 m, and the inset in Figure 4 shows that these data also overlap with snow and ice identified through our analysis of Landsat 7 imagery. The caribou collar data indicate abundant summer caribou activity near the continental divide, but they also show that some caribou began to migrate eastward to their winter range during the summer months (Creighton, 2006). We focused our survey efforts on areas of high caribou activity near the continental divide, as these areas appeared to exhibit more late-lying snow and ice patches in our imagery analysis. In addition, the traditional trail data, especially in the absence of a well-documented archaeological record in our study area, provided confidence that these areas were significant to ancient hunters. Overlaying the 28 ice patch target sites identified through our field surveys on these maps demonstrates that these datasets provided a useful modeling tool for locating ice patch archaeological sites.

Field Surveys

Over the five field seasons, we inspected more than 100 locations, from which 28 target ice patches were identified (Fig. 3). The patches are typically located on north- and northeast-facing slopes at elevations of 1675 to 1950 m asl. The patches range in length from 25 to 500 m or more, with widths of 5 to 50 m or more. Thickness varies from less than 1 m to more than 6 m. A defining feature of all of these ice patches is that they preserve extensive deposits of caribou dung.

We classified these ice patches as "permanent" (if a permanent ice core was present) or "intermittent." Ten of the 28 ice patches have ice cores and appear to have been relatively permanent features. Of the 10 permanent ice patches, 4 produced both artifacts and faunal remains, 5 produced only faunal remains, and only 1 has so far failed to produce any targeted remains. The remaining 18 ice patches are intermittent patches. While some of the intermittent patches exist in multiple consecutive years and have small ice cores, these features were unstable over the term of our fieldwork, and the amount of ice and snow varied dramatically during the years that we studied them. Of the 18 intermittent ice patches, 4 produced organic artifacts and faunal remains, 5 produced only faunal remains, and 9 have, so far, produced nothing. This distribution suggests that intermittent patches provide relatively stable preservation environments for artifacts and biological specimens, although not as stable as those provided by permanent ice patches. This is not surprising given the elevation, low annual temperatures, protection from intense UV radiation, and annual snow coverage for much of the year that these places experience.

While in the field, we also took the opportunity to inspect a wide variety of ice and snow patches that ultimately proved to have low potential for archaeological deposits. Many of these were in precipitously steep terrain on mountains with rugged peaks. Although we inspected a large number of these patches on foot, no evidence of human presence was noted, despite the fact that many appeared to be used by caribou in summer. Through our discussions with Shúhtagot'ine Elders (see Andrews et al., 2012), it became clear that to hunt at ice patches, humans had to approach from the top. Thus, such hunting required a mesa-type mountain with a rounded top, which allowed hunters to climb the south-facing side undetected by the caribou and hunt down on the north-facing ice patch (cf. VanderHoek et al., 2007b). If hunters approached from below or beside the patches, they would be easy to see from a great distance, allowing caribou ample time to flee.

We also inspected many valley or trough patches (cf. "longitudinal" patches, VanderHoek et al., 2007b). These ice patches, protected from summer insolation by shadows created by valleys, crevices, and troughs on mountain slopes, are used by caribou, but we were unable to find any evidence of human hunting on these features. We also found no evidence of the use of blinds or large-scale entrapment devices associated with ice patches.

Ice patch size varied significantly from year to year. Meulendyk et al. (2012) present maps showing changes in the perimeters of ice patch archaeological sites KfTe-1 and KhTe-2 between 2007 and 2009. Weather patterns for the years 2005, 2007, and 2009 produced colder-than-average winter temperatures and greater amounts of snow than in preceding winters. The 2008 field season, which followed a milder winter with less precipitation, had less snow and greater exposure, providing access to areas that had been inaccessible in previous years, especially at KfTe-1. In 2010 we observed significant melting, greater than in any preceding year: five patches had been reduced by more than 90% from the previous summer, and all others were reduced by smaller degrees. Yet, even with this remarkable degree of melting, portions of some patches—available for inspection in other years—were covered by the previous winter's snow, indicating that variation occurs at micro-environmental levels. The pattern of artifact recovery at KhTe-2 provides a specific example of this variation. We collected two mid-shaft fragments of an arrow at KhTe-2 in 2007. Returning to the site in 2009, though portions we had examined in 2007 were now covered with last winter's snow, we found the area above the arrow find newly exposed, revealing the remaining four shaft sections and three feathers used as fletching (see ARTIFACT DESCRIPTIONS, below). Predicting these changes might be important for gauging the cost of forthcoming field seasons. However, this is difficult to do, as broad measures of climate change like Melting Degree Days (Farnell et al., 2004:252–253) are useful for determining long-term trends, but less useful for predicting snow cover in coming months.

ARTIFACT DESCRIPTIONS

Artifacts collected from ice patch archaeological sites in the Selwyn Mountains represent elements of three precontact weapons systems: throwing-dart (atlatl) technology, bow-and-arrow technology, and snare technology. Table 1 provides summary data—including AMS dates and wood species identifications—for the wood components of all artifacts collected to date. In this section, we present detailed descriptions of these artifacts and compare them to artifacts emerging from ice patch archaeological sites in other areas of northwestern North America.

Throwing-Dart Technology

The distal ends of two darts represent throwing-dart technology in the Northwest Territories ice patch assemblage (Fig. 5). Artifact KiTf-1:1 consists of two fragments that refit to form the distal end of a dart shaft (Fig. 5d). The hafting element at the distal end of this artifact consists of a U-shaped slot that is 11 mm deep and 5 mm wide. Manufactured from a birch (*Betula* sp.) stave extracted from a small-diameter branch or trunk (Alix, 2008), this dart shaft fragment is 389 mm long and has a maximum diameter of 9.6 mm. This artifact dates to 2410 ± 40 ^{14}C yr BP (ca. 2520 ± 180 cal. yr BP).

Artifacts KhTf-2:1–3 were found in direct association in the ablation zone of ice patch archaeological site KhTf-2. These artifacts, which include a complete foreshaft, a broken stone projectile point, and a small fragment of the main shaft of the dart, fit together to form the distal end of a dart with a detachable foreshaft. Artifact KhTf-2:1 consists of two pieces that refit to form a foreshaft with a slotted hafting element at its distal end (Fig. 5b). The U-shaped blade

TABLE 1. Summary data for the wood components of all artifacts collected to date. Radiocarbon dates were calibrated using CALIB6.0 (Stuiver et al., 2005) and the INTCAL09 dataset (Reimer et al., 2009). Calibrated dates in the text are represented with a median age.

Artifact #	Artifact type	Wood taxon	Laboratory #	Conventional Age ^{14}C yr BP	Calibrated age ranges (2σ range)	Median calibrated age (cal. yr BP ± 95% CI)
KgTe-1:3	arrow shaft	*Betula* sp.	Beta-240096	270 ± 40	0 – 464	230 ± 230
KhTe-2:1	arrow shaft	*Betula* sp.	Beta-240097	340 ± 40	308 – 488	400 ± 90
KhTe-1:15	self bow	*Salix* sp.	Beta-216916	340 ± 50	306 – 497	400 ± 100
KfTd-2:1	arrow shaft – distal end	*Betula* sp.	Beta-256285	570 ± 40	521 – 650	590 ± 70
KfTe-1:11	arrow shaft – distal end	*Picea* sp.	Beta-256287	850 ± 40	684 – 904	790 ± 110
KfTe-1:10	snare	*Salix* sp.	Beta-248993	970 ± 40	791 – 955	870 ± 80
KhTf-2:1	dart foreshaft	*Amelanchier* sp.	Beta-240099	2310 ± 40	2157 – 2452	2300 ± 150
KhTf-2:3	dart shaft fragment	*Betula* sp.	Beta-256356	2350 ± 40	2211 – 2676	2440 ± 230
KiTf-1:1	dart shaft – distal end	*Betula* sp.	Beta-240098	2410 ± 40	2345 – 2699	2520 ± 180

slot is 14 mm deep and has a maximum width of 8 mm. The proximal end of this piece is tapered to fit into a socket at the distal end of the dart shaft. The complete foreshaft is 322 mm long and has a maximum diameter of 14 mm. This artifact was manufactured from a branch or sapling of saskatoon berry (*Amelanchier* sp., cf. *Amelanchier alnifola*) (Alix, 2008) and dates to 2310 ± 40 ^{14}C yr BP (ca. 2300 ± 150 cal. yr BP).

Artifact KhTf-2:2 is a broken, corner-notched stone point with a straight base, which has at least 18 thin strands of sinew lashing wrapped around its neck (Fig. 5a). While the maximum thickness of the point is 8.5 mm, its base is thinned to fit into the blade slot in the foreshaft. A snap fracture in the blade section of the point and a damaged shoulder are the result of impact. The projectile point fragment is 36.5 mm long and 29.6 mm wide. It has a lenticular cross section and is made of dark grey chert.

Artifact KhTf-2:3 is a small fragment of the distal end of a dart shaft made from a birch (*Betula* sp.) stave (Fig. 5c). This artifact measures 68.9 mm in length and 11.9 mm in width. The distal end of the inner face of this piece contains a carved socket that articulates well with the tapered proximal end of the foreshaft. The outer surface of the shaft fragment exhibits four parallel notches. We suspect that these notches were fashioned to hold lashing for securing the foreshaft to the shaft. This artifact dates to 2350 ± 40 ^{14}C yr BP (ca. 2440 ± 230 cal. yr BP). Significant overlap of the calibrated age ranges for the foreshaft (2157–2452 cal. yr BP) and shaft fragment (2211–2676 cal. yr BP) provide further evidence of the association of these artifacts.

Throwing-dart technology in northwest North America is best characterized by the large assemblage of throwing darts collected from ice patch archaeological sites in Yukon Territory (Hare et al., 2004, 2012). Some general characteristics of the artifacts in this collection include a dimple at the proximal end of the dart shaft for articulation with the spur on a throwing board, and a large slotted hafting element at the distal end of a shaft or foreshaft fashioned to accommodate a large stone projectile point. The shafts of complete darts are long and flexible and tend to taper towards a maximum diameter at their distal ends.

Both artifacts from the Selwyn Mountains identified as throwing darts have a large slotted hafting element designed to accommodate a large stone projectile point. Despite the similarities of these artifacts with the distal ends of throwing darts found in Yukon Territory, their unequivocal classification as throwing darts remains slightly problematic. One of the definitive characteristics of throwing-dart technology is the presence of the dimple at the proximal end of the dart shaft that fits into the spur on a throwing board. As we have not collected the proximal ends of any darts to date, it is difficult to discount the possibility that these artifacts are light spears of some kind. Yet, the ages of these artifacts fit within the chronology of throwing-dart technology in adjacent Yukon Territory (spanning 8360 ^{14}C yr BP to 1250 BP), and thus it is reasonable to expect that this technology was also in use in the Selwyn Mountains (Hare et al., 2004).

While the distal dart shaft fragments from the Selwyn Mountains are very similar in age, they are morphologically quite distinct. One artifact incorporates a foreshaft made from a sapling or branch of saskatoon berry (*Amelanchier* sp.) that fits into a socket on a main shaft made from a birch stave, while the other appears to consist of a single shaft made from a birch stave. Technological and morphological diversity also characterize the Yukon throwing-dart collection (Hare et al., 2004). For example, Hare et al. (2004) note that while birch was the preferred wood for shaft manufacture, saplings and staves were selected in roughly equal numbers. Single dart shafts and composite darts with foreshafts are also present in similar frequencies, and while foreshafts are most commonly made from wood, antler foreshafts are also present. Most darts were armed with large stone projectile points, but there are also several examples of antler projectile points. These variations in throwing-dart design appear to lack clear temporal patterning (Hare et al., 2004).

Bow-and-Arrow Technology

Five artifacts characterize bow-and-arrow technology in the Northwest Territories ice patch assemblage (Fig. 6). These artifacts include a medial section of a self bow (i.e., a bow made from a single piece of wood), two nearly complete arrows, and two distal arrow shaft fragments.

The self bow (see Fig. 6) was found in 15 fragments scattered across a flat bench above ice patch KhTe-1. Although this artifact dates to 340 ± 50 ^{14}C yr BP (ca. 400 ± 100 cal.

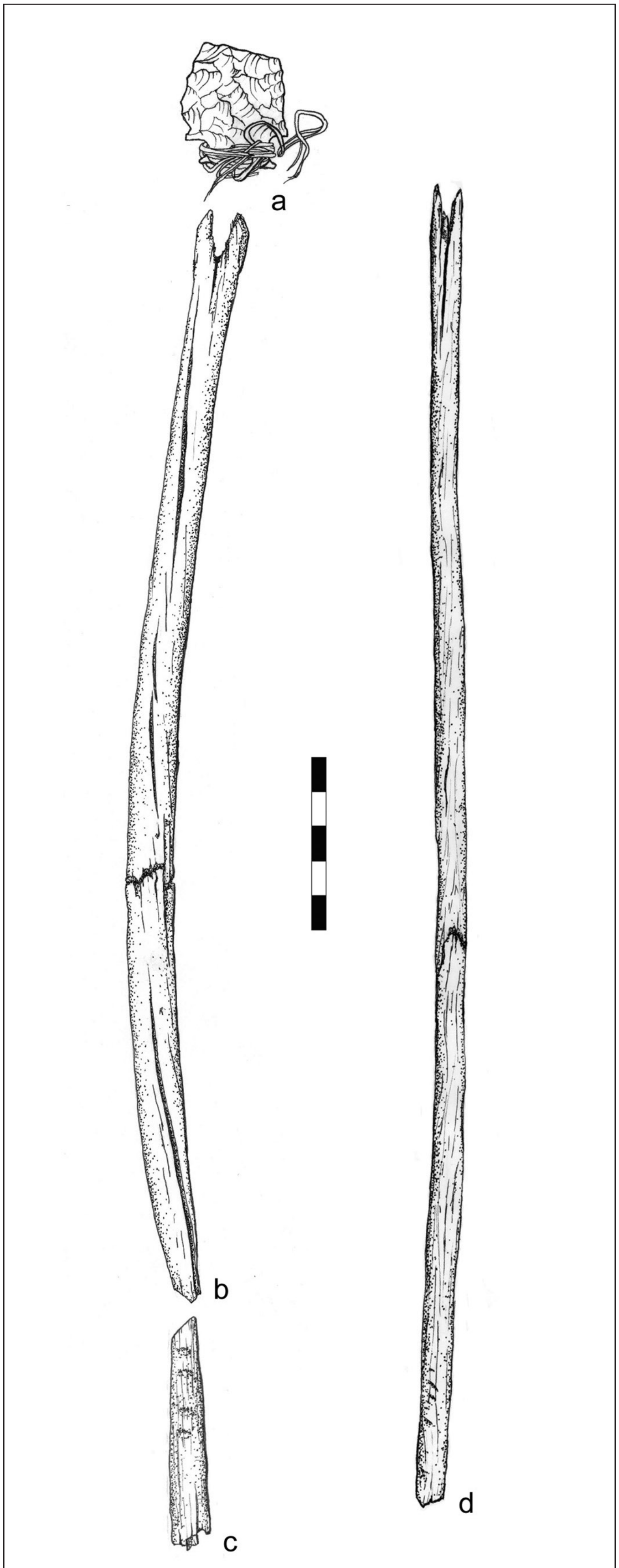

FIG. 5. Throwing-dart artifacts recovered from ice patch archaeological sites: (a–c) KhTf-2; (d) KiTf-1. Scale bar equals 5 cm.

yr BP), the provenience and heavily weathered appearance of the wood pieces indicate that the bow was not protected by permanent ice. Ten of the 15 fragments refit to form a medial section of a bow missing both nock ends (Fig. 6a). Measuring approximately 1080 mm in total length, the bow has a roughly plano-convex cross section with a slightly convex belly and a flat back. While most of the lower end of the bow is missing, the upper end tapers towards the missing nock end. The maximum width and thickness of the artifact are approximately 31 and 20 mm, respectively. This artifact was manufactured from a flat-grained willow (*Salix* sp.) stave (Alix, 2008). The bow failed at its upper end, delaminating and splitting in an area where the grain of the wood is particularly twisted, which explains why it was discarded (Alix, 2008).

Bows are rare in the archaeological record of ice patches in northwestern North America. The only other specimen—collected from an ice patch in Yukon Territory—is also a self bow (Hare et al., 2004). Manufactured from maple (cf. *Acer glabrum*; Hare et al., 2004:267), this incomplete bow consists of a medial segment and two end segments with paired square notches for string attachment.

Artifacts KhTe-2:1–6 consist of six shaft fragments that refit to form a complete arrow shaft (Figs. 6e and 7). Manufactured from a birch (*Betula* sp.) stave, the arrow shaft is 858 mm long and has a maximum diameter of 8.14 mm. The point of maximum diameter is located in the proximal half of the arrow shaft. The distal end of the arrow consists of a small, corner-notched projectile point hafted in a split blade slot and secured with sinew lashing. The hafted arrowhead is approximately 31 mm long, 13.5 mm wide, and 3 mm thick. An x-ray of the distal end of the arrow shows that the arrowhead has a convex base (see Fig. 11g). The proximal end of the arrow shaft has an open U- or V-shaped nock. Three well-preserved pieces of fletching were found in direct association with the arrow shaft fragments (Fig. 8). These pieces measure approximately 240–250 mm in total length. The rachises, or main shafts of the feathers, are split longitudinally over approximately half of this length, resulting in a relatively flat face on the inner side of the fletching to facilitate attachment to the arrow shaft. On the outer side, the barbs of the feather are trimmed so that they form an arc with a width of less than 1 mm at the distal end of the fletching and a width of approximately 10–12 mm at the proximal end. Species identification through examination of morphological characteristics is impossible because the feathers were trimmed, removing essential features. However, the size and colour of the feathers suggest it is likely that they came from a large raptor (species of eagles, owls, and ospreys are common in the area) or from a goose (several species nest in the area in summer or migrate through the area in fall and spring). The only missing component of this arrow is the lashing for attaching the fletching to the arrow shaft. The arrow dates to 340 ± 40 ^{14}C yr BP (ca. 400 ± 90 cal. yr BP).

Artifacts KgTe-1:2–5 consist of four fragments that refit to form a nearly complete arrow shaft manufactured from

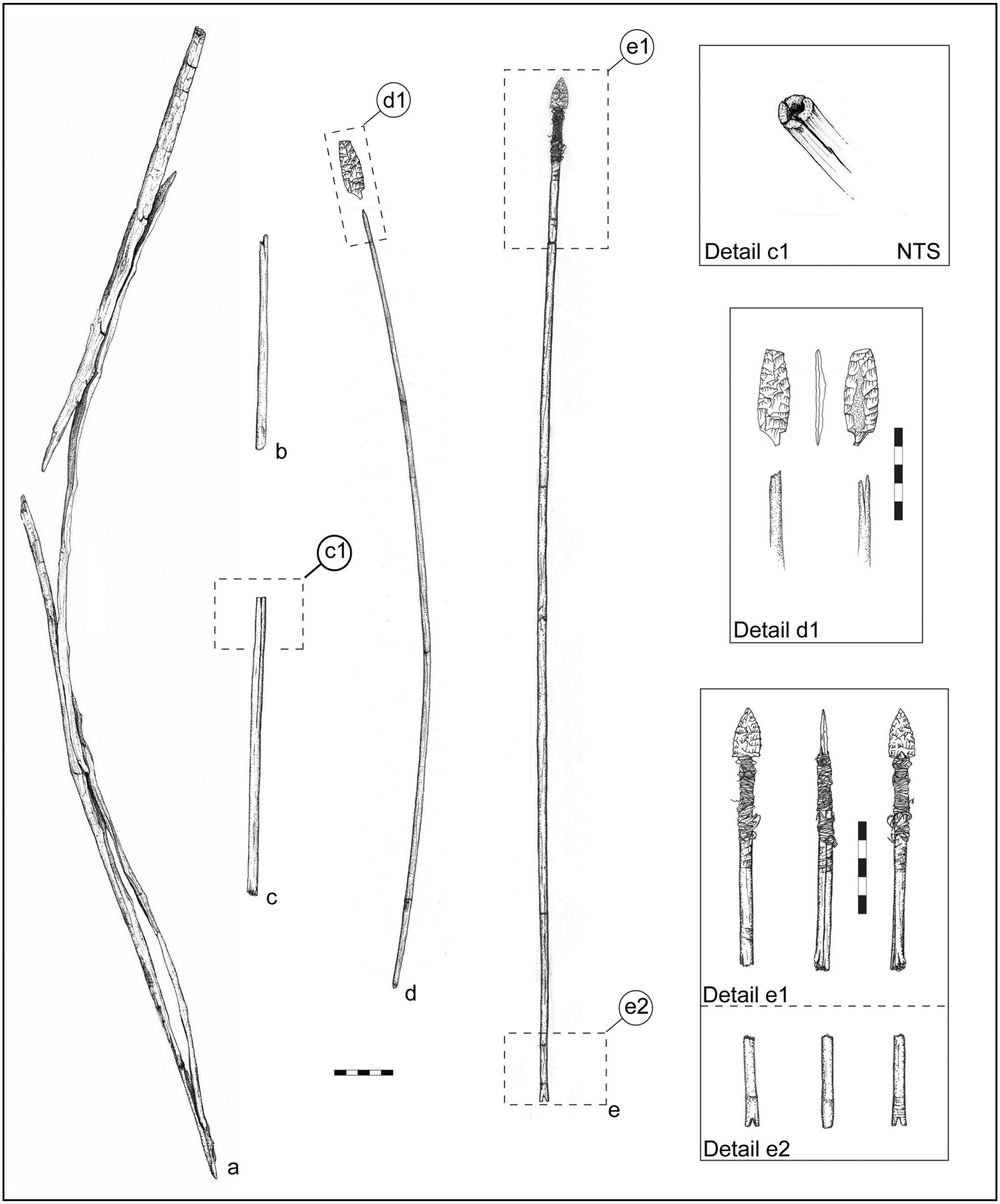

FIG. 6. Archery artifacts recovered from ice patch archaeological sites: (a) KhTe-1; (b) KfTd-2; (c) KfTe-1; (d) KgTe-1; (e) KhTe-2. Scale bar equals 5 cm.

a birch (*Betula* sp.) stave (Alix, 2008) (Fig. 6d); it dates to 270 ± 40 ^{14}C yr BP (ca. 230 ± 230 cal. yr BP). This shaft is missing its proximal nock end, and thus we represent the length of the arrow as greater than 792.9 mm. The point at

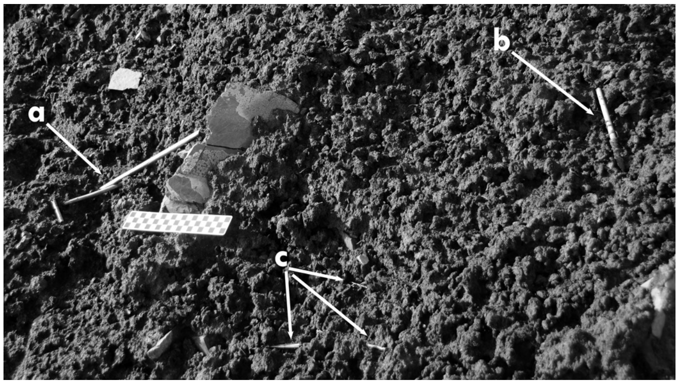

FIG. 7. Fragments of a birch arrow found at KhTe-2 in 2009: (a) the proximal end with nock and two mid-shaft fragments; (b) the distal end with hafted stone projectile point; (c) the remains of three feathers used as fletching.

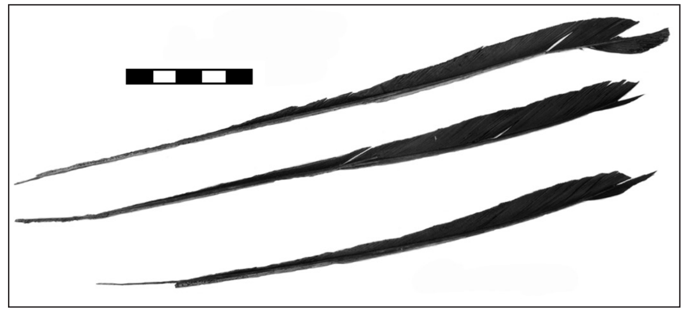

FIG. 8. Fletching recovered from ice patch archaeological site KhTe-2 in 2009. Scale bar equals 5 cm.

which the shaft achieves its maximum diameter of 8.66 mm is located within the proximal half of the arrow. From this point, the arrow tapers towards both its proximal and distal ends. The hafting element at the distal end of the shaft consists of a simple split parallel to the grain of the wood. The shaft fragments were found in direct association with a small stone projectile point that fits in this blade slot. While this point (KgTe-1:1) is missing its distal tip and its base is damaged, it appears to be a stemmed form with angular shoulders. It is 51.86 mm long, 17.19 mm wide, and 4.49 mm thick, and has a plano-convex cross section.

Artifact KfTd-2:1 is the distal end of an arrow made from a birch (*Betula* sp.) stave (Alix, 2009) (Fig. 6b). The proximal end of this shaft exhibits a double beveled scarf joint, which indicates that this piece is the distal end of a repaired arrow shaft. Like the arrow found at ice patch KgTe-1, the distal end of this artifact has a hafting element consisting of a simple split fashioned to accommodate a small stone projectile point. This shaft segment is 209 mm long and has a maximum diameter of 8.22 mm. It dates to 570 ± 40 ^{14}C yr BP (ca. 590 ± 70 cal. yr BP).

Artifact KfTe-1:11 is also a distal arrow shaft fragment. In contrast to the other arrows found in the Selwyn Mountains, this artifact was manufactured from a spruce (*Picea* sp.) stave rather than a birch stave (Alix, 2009) (Fig. 6c). The hafting element at the distal end of this piece is also distinct, consisting of a socket designed to articulate with the conical tang of a bone or antler arrowhead rather than a split to accommodate a small stone point. Lashing marks are evident at the distal end of the shaft. The distal end also exhibits two long splits on the flat-grained face of the shaft and two shorter splits along the edge-grained face of the shaft, which are the result of a hafting process in which the conical tang of an osseous arrowhead was forced into the shaft (Alix, 2009). The shaft fragment is 258 mm long and has a maximum diameter of 9.53 mm; it dates to 850 ± 40 ^{14}C yr BP (ca. 790 ± 110 cal. yr BP).

Recent work to compile comparative data for all of the arrows in the Yukon and Northwest Territories ice patch assemblages indicates that the observed technological and morphological differences between the spruce and birch arrows noted above are part of a larger regional pattern. Alix et al. (2012) develop a typology of arrows (n = 27) collected from ice patches in the Northwest Territories and Yukon, which identifies relatively long birch arrows with small stone projectile points and relatively short spruce arrows with antler projectile points as distinct types that appear to overlap in time and space in this region. In fact, when the Yukon and Northwest Territories collections are considered together, Alix et al. (2012) are able to find very little chronological patterning in the distribution of these two distinct arrow types over the past 1000 years. Possible interpretations of the stable co-occurrence of these two types are discussed by Alix et al. (2012). Several arrows collected in the Wrangell-St. Elias Mountains of Alaska are similar to the spruce arrows from the Yukon and Northwest Territories in that they have closed sockets for an antler arrowhead and are similar in length and symmetry, although Dixon et al. (2005) do not provide wood species data for these artifacts. VanderHoek et al. (2007b) report a spruce arrow with an associated antler arrowhead from central Alaska. In contrast to several examples from Yukon ice patches (Hare et al., 2004), none of the arrows from the Selwyn Mountains show obvious signs of ochre decoration.

Snare Technology

Figure 9 illustrates a spring-pole snare found at the base of ice patch archaeological site KfTe-1. The spring pole consists of an unmodified willow branch (*Salix* sp.), approximately 555 mm long and 9.7 mm in maximum diameter. Recovered in several fragments, the snare line is approximately 380 mm in total length. The proximal end of the line is tied to the widest-diameter portion of the spring pole, and the distal end terminates in a partially closed noose. The snare line consists of two strands of sinew twisted into a two-ply line. This artifact dates to 970 ± 40 ^{14}C yr BP (ca. 870 ± 80 cal. yr BP).

Spring-pole snares were used widely by the Aboriginal groups of northern North America to harvest a variety of small animals (Cooper, 1978). The snare found at KfTe-1 is similar to the spring-pole snares set by the Shúhtagot'ine and other Northern Athapaskans to catch ground squirrels. The presence of ground squirrel holes downslope of KfTe-1 indicates that these animals establish dens near alpine ice

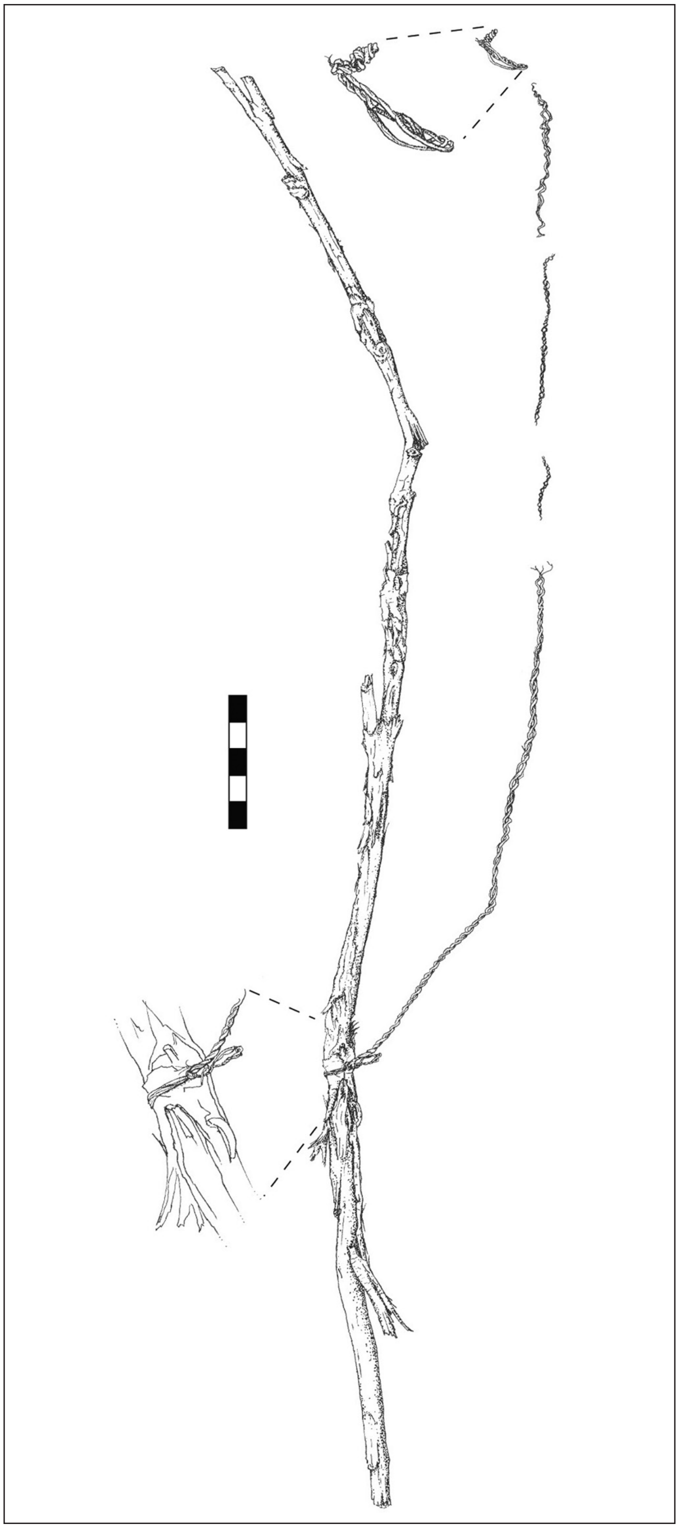

FIG. 9. Ground squirrel snare recovered from ice patch archaeological site KfTe-1. Scale bar equals 5 cm.

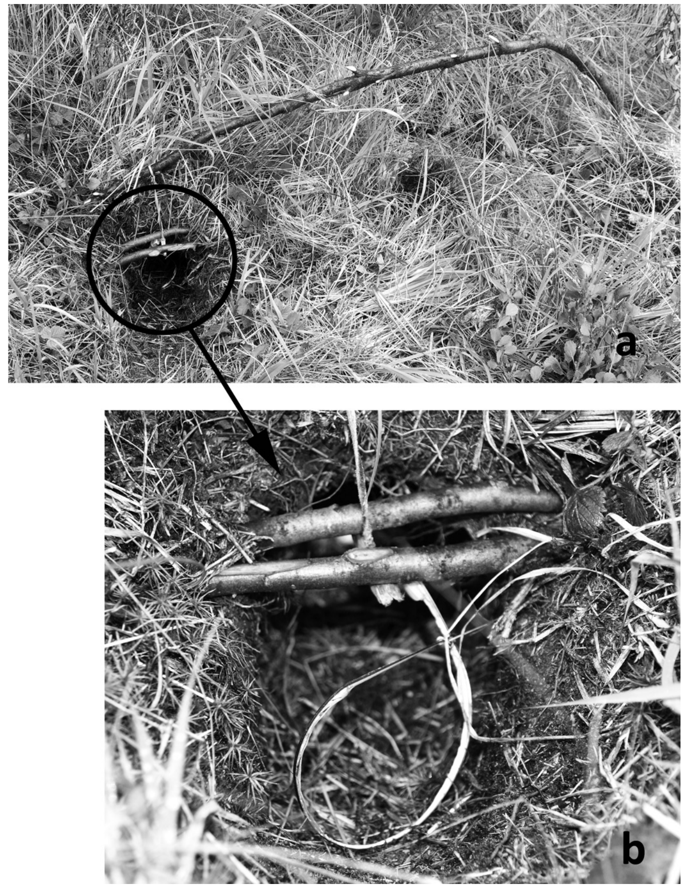

FIG. 10. Photograph of a ground squirrel snare set by a Shúhtagot'ine Elder at O'Grady Lake in 2008. The spring pole snare (a) uses a split eagle feather quill for the noose (b).

patches. Figure 10 shows a snare set at the entrance to a ground squirrel hole by a Shúhtagot'ine Elder. A piece of babiche line is used to connect the spring pole—a green willow branch lodged in the ground next to the ground squirrel hole—to a noose fashioned from the split shaft of an eagle feather. A small trigger stick is tied to the line just above the noose. Two sticks positioned at the top of the hole hold the trigger stick and noose in place. When the trigger stick is dislodged by the movement of a ground squirrel, the spring pole lifts and tightens the noose around the animal, strangling it against the two sticks placed above the entrance hole.

The snare found at KfTe-1 differs from this model in that the entire snare is made with twisted sinew line rather than having a babiche line attached to a noose made from an eagle feather shaft. Ethnographic data indicate that Northern Athapaskans used both types of snare line for snaring small animals (McClellan and Denniston, 1981; McClellan, 2001). McClellan (2001:158), for example, notes that the people of southwest Yukon Territory sometimes made an entire ground squirrel snare of twisted sinew, but more often the noose was made from "the springy midrib of an eagle or crow feather and attached to a thong of moose or caribou babiche." Setting a snare with a sinew noose likely necessitated the use of small twigs to hold the noose in an open configuration (Cooper, 1978).

The snare collected at KfTe-1 is also missing the small trigger stick necessary for setting a spring-pole snare. While this piece may have been lost during use of the snare or through post-depositional processes, it is also possible that this artifact was used as a tether snare rather than a spring-pole snare. Tether snares do not have a spring mechanism and thus do not require a trigger stick. Animals caught in the noose of a tether snare are killed by struggling against a rigid immovable object like a stick driven into the ground or a tree (Osgood, 1970; Cooper, 1978). The Northern Athapaskan ethnographic record indicates that tether snares made of twisted sinew were used to catch ground squirrels by the Ingalik, who set these snares in the mountains in the spring and fall (Osgood, 1970). In our view, however, the small-diameter willow branch found at KfTe-1 would not be an effective anchor for a tether snare, and thus we think it is more likely that the snare mechanism depended on the spring force of the willow branch.

An artifact recovered from an ice patch in central Alaska also relates to ground-squirrel snaring technology. VanderHoek et al. (2007a) describe a "gopher stick" consisting of a long spruce stave with a deep notch at its distal end and a point at the proximal end. They suggest that this artifact is morphologically similar to a tool used by the Southern Tutchone people of southwest Yukon to set ground squirrel snares. The snares set using this device differ from the Shúhtagot'ine spring-pole snare in that they are set several centimeters inside the ground squirrel hole rather than right at the entrance (McClellan and Denniston, 1981; McClellan, 2001). In this case, the pointed end of the "gopher stick" is used to poke a hole from the ground surface into the ground squirrel hole, and the hooked end is used to draw the snare line through the hole so that it can be attached to the spring pole. The "gopher stick" dates to 390 ± 40 ^{14}C yr BP (VanderHoek et al., 2007a, 2012).

Miscellaneous Stone Artifacts

The Northwest Territories ice patch artifact assemblage also includes three stone projectile points that were not found in association with organic components (Fig. 11). Artifact KhTe-1:16 is the medial section of an arrowhead, measuring 37.34 mm long, 18.06 mm wide, and 2.94 mm thick (Fig. 11d). A snap fracture at the distal end of the arrowhead and an apparent bending fracture with a shallow step termination in the neck portion of the point are indicative of impact breakage (Fischer et al., 1984; Odell and Cowan, 1986). The remnants of symmetric notches at the proximal end of the point suggest that this point was a notched form of some kind.

Artifact KfTd-1:1 is a lanceolate point with a plano-convex cross section (Fig. 11c). It measures 40.2 mm long, 23.2 mm wide, and 6.5 mm thick. This point has a resharpened distal tip. The proximal end consists of a bending fracture with a step termination, but it is unclear if this represents impact breakage leading to discard or loss of the point at ice patch KfTd-1 or a previous break that was used for the base of the point. Minor edge-grinding is evident on the proximal edges of the point.

Artifact KfTe-1:9 is a large foliate point or knife with a thin, lenticular cross section and convex base, measuring 111.93 mm long, 26.13 mm wide, and 7.2 mm thick (Fig. 11a). This point has very straight margins, and both faces exhibit a precise parallel-oblique pressure flaking pattern. On each face, the pressure flakes removed from one margin extend well across the midline of the piece. This long set of flakes was removed from opposite margins on opposite faces. Marked proximal edge-grinding on both margins extends approximately 32 mm from the base of the point.

Artifact Chronology

The calibrated age ranges presented in Table 1 show that dart technology (2157 – 2699 cal. yr BP) predates arrow technology (0 – 904 cal. yr BP) in the Selwyn Mountains. While these data are consistent with the chronology established for Yukon ice patch artifacts, which shows an abrupt transition from dart technology to arrow technology at approximately 1200 ^{14}C yr BP, more data are needed to determine the timing of this transition in the Selwyn Mountains.

FAUNAL ANALYSIS

We collected all of the faunal osteological material found near ice patches in the Selwyn Mountains. Over 250 specimens were collected from 18 ice patches; of these, we have analyzed 172 elements to date. Ice patches with permanent ice cores produced 101 specimens, or 60% of the identified specimens, while intermittent patches accounted for 71 specimens (40%). Preservation was typically very good, and many elements, despite being sometimes thousands of years old, still retained some adhering soft tissue and exhibited the coloration of fresh specimens. Identifiable caribou bones were radiocarbon-dated to develop an ice patch chronology (see Galloway et al., 2012) and to provide dated specimens for genetic analysis (see Letts et al., 2012). Generally, caribou bones ranged from modern to 3510 ± 40 ^{14}C yr BP (ca. 3770 ± 120 cal. yr BP). Caribou dung samples were collected from 10 cores extracted from three ice patches. The drill core samples were radiocarbon-dated to help understand ice patch formation and morphology (see Meulendyk et al., 2012), but also to provide dated samples for paleoenvironmental analyses (Galloway et al., 2012). Dung samples taken from the cores ranged in age from 140 ± 40 ^{14}C yr BP (ca. 140 ± 140 cal. yr BP) to 4580 ± 40 ^{14}C yr BP (ca. 5250 ± 200 cal. yr BP)

Among the osteological remains, large mammal bones predominate (n = 150) and of these the majority are caribou (n = 115). Sheep (*Ovis* sp.) and moose are each represented by a single specimen. The single moose left humerus recovered from intermittent ice patch 8T1 returned a date of 3520 ± 40 ^{14}C yr BP (ca. 3800 ± 100 cal. yr BP). The remaining large mammal remains (n = 33) cannot be identified to genus. Small mammals, represented by only 11 specimens, include wolverine (n = 2), marmot (n = 6), and ground squirrel (*Spermophilus* sp. cf. *Spermophilus parryii*, n = 3).

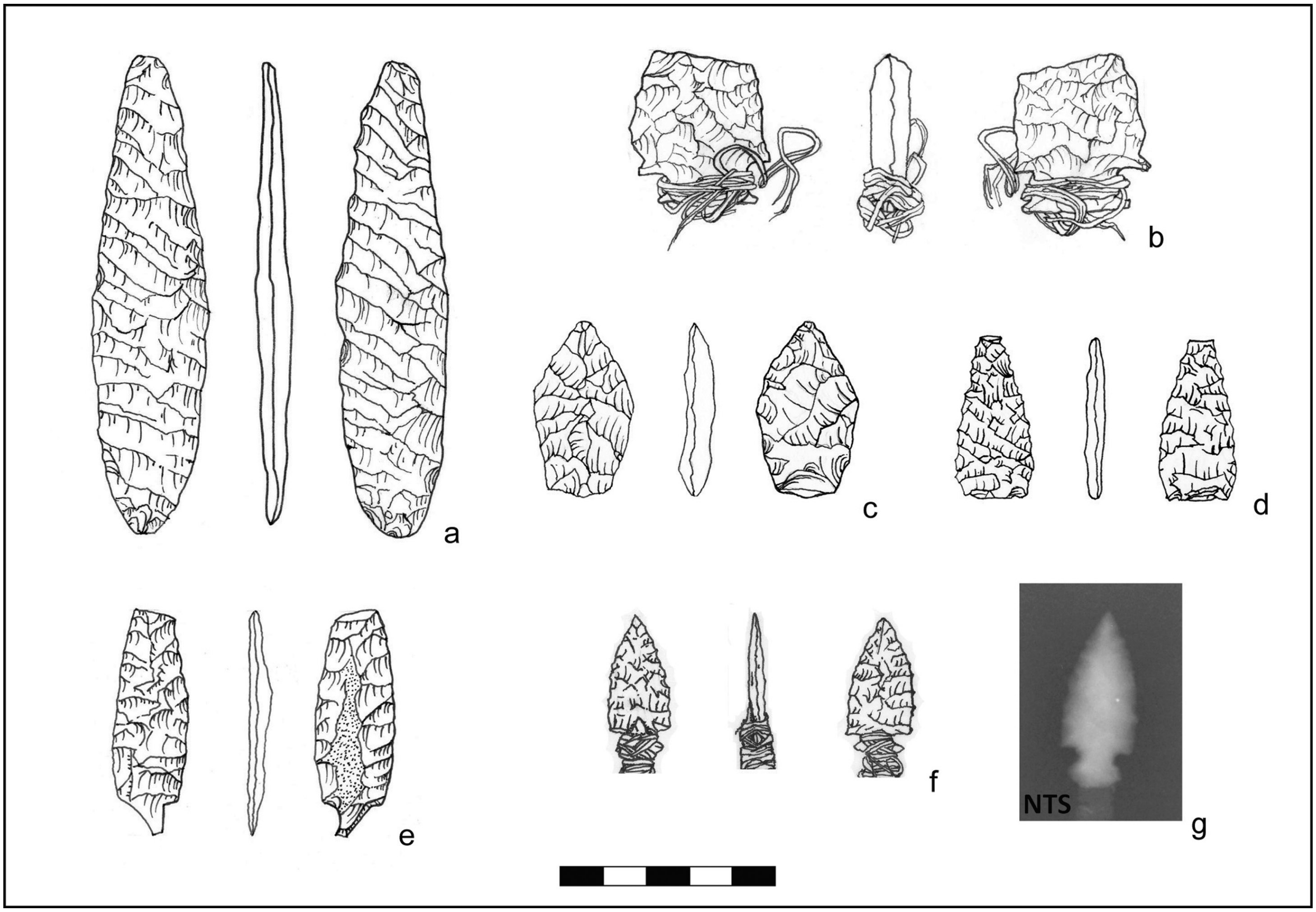

FIG. 11. Bifaces recovered from ice patch archaeological sites: (a) KfTe-1; (b) KhTf-2; (c) KfTd-1; (d) KhTe-1; (e) KgTe-1; (f, g) KhTe-2. Scale bar equals 5 cm.

Of the Aves osteological remains collected, only 5 of 10 specimens could be identified to at least family or tribe level, with two specimens identified as goose and three as gull or duck. Remains of 10 feathers (including three used as fletching for an arrow; see above) were also recovered but have not been identified.

Aside from the three feathers used as fletching, none of the faunal remains showed cut marks or other signs of butchering. Analysis of caribou bones in the assemblage shows that examples of most major skeletal elements are present, though nearly all of the bones show evidence of being processed by carnivores and rodents (Matheus, 2008; Nomokonova, 2009). Observations over more than three decades of travelling with Dene hunters in the Northwest Territories indicate that long bones, thoracic and lumbar vertebrae, and ribs are frequently transported away from kill sites to be processed elsewhere. As well, Shúhtagot'ine Elders tell us that, as in other Dene groups, animals killed at important persistent hunting features (like salt licks and fences) would be butchered away from the site to ensure that the blood did not "spoil" the site (see Andrews et al., 2012). These observations led us to conclude that the assemblage is a natural death assemblage and not one resulting from human predation.

DISCUSSION: PRECONTACT HUNTING ON ICE PATCHES IN THE SELWYN MOUNTAINS

Alpine ice patches in the Selwyn Mountains provided precontact hunters with locations where they could expect to intercept and harvest caribou (Hare et al., 2004; Dixon et al., 2005; VanderHoek et al., 2007b). As discussed above, Ion and Kershaw's (1989) observations of caribou behaviour in the Selwyn Mountains show that caribou seeking relief from insect harassment and warm summer temperatures make use of high-elevation ice patches. On afternoons when high air temperatures and low wind speeds prevail in the alpine valleys, caribou move from valley bottoms to ice patches in the late morning and descend in the late afternoon or evening. Some of the ice patches used by caribou in the Selwyn Mountains are relatively permanent features, containing ice that predates 4580 ± 40 ^{14}C yr BP (ca. 5250 ± 200 cal. yr BP); others are intermittent patches that can survive several consecutive years but melt out during the warmest summers. These intermittent patches tend to form in the same locations over time and thus provide predictable relief habitat for caribou in most summers. Interestingly, in the summer of 2010, a warm year in which several intermittent ice patches melted out completely, caribou continued to use the patches as relief habitat, bedding down in the cool wet dung exposed by the melted snow. As places of repeated seasonal use, ice patches in the Selwyn Mountains can be thought of as persistent places in the alpine landscape (cf. Schlanger, 1992).

As predictable-harvesting locations, ice patches helped alpine hunter-gatherers to meet one of the primary challenges faced by precontact caribou hunters throughout the circumpolar world: anticipating where and when animals would be found on the landscape (Ingold, 1980). Yet even after caribou had been located, hunters still had to secure shots within the effective range of their weapons (Blehr, 1990). We think that alpine ice patches provided hunters with favourable topography for stalking small groups of animals at close range. Most of the ice patches in the Selwyn Mountains that contain evidence of precontact hunting activity are located just beneath the crests of domed mesa-like summits that rise gently from high alpine valleys. Ice patches of this kind provided not only access from the valleys below, but also a topographic advantage for hunters. During our traditional knowledge work to document Shúhtagot'ine perspectives on hunting at ice patches, several Elders noted that hunting these features from above allowed hunters to approach caribou at close range using the crest of the hill as cover (Andrews et al., 2012). VanderHoek et al. (2007b:79) suggest that the diurnal wind shift also facilitated hunting ice patches from above:

> Summer nights in mountain valleys experience cool downdrafts, while days often have warm up-drafts coming up the valley and over the ice patch from below. This allows hunters to stalk the caribou from across the top of the ridge and come down on their quarry from above, both unseen and undetected by smell.

We think that the presence of topographic characteristics that facilitated this kind of hunting strategy is an important indicator of whether or not an ice patch was used by precontact hunters. While we have observed caribou using ice patches and late-lying snow packs situated in steeper, more rugged terrain, our survey data indicate that these sites were less attractive, or accessible, to human hunters.

The emerging archaeological record of alpine ice patches raises important questions about hunter-gatherer adaptations to the high alpine environment of the Selwyn Mountains. What role did alpine ice patches play in the subsistence and settlement systems of precontact hunter-gatherers in this region? We know that alpine ice patches were more than specialized caribou kill sites. Artifact data from both interior Alaska and the Northwest Territories indicate that ground squirrels were also harvested near ice patches (VanderHoek et al., 2007a). While it is clear that nutrient-rich runoff from melting ice patches promotes the growth of specialized vegetation communities downslope of ice patches (VanderHoek et al., 2007a; Green and Pickering, 2009), further research is required to determine whether this process enhances ground-squirrel habitat to the extent that ice patches were exceptional locations for ground squirrel harvesting.

The distribution of ice patch archaeological sites in the Selwyn Mountains offers further clues for understanding the role of alpine ice patches in precontact land use patterns. As shown in Figure 4, four of the ice patch archaeological sites are located less than 16 km from O'Grady Lake, a major fish-bearing lake in the Selwyn Mountains. O'Grady Lake is located in a broad alpine valley known to the Shúhtagot'ine as K'atieh, or willow flats, and the lake itself is surrounded by an extensive wetland complex, recognized by Shúhtagot'ine Elders as excellent moose habitat. The four ice patches are situated on domed summits that rise gently from this valley and thus were easily accessible from the valley bottom. Recent archaeological survey efforts identified evidence of a multi-component campsite at the outlet of O'Grady Lake, but further work is needed to develop a detailed picture of precontact land use in this area. The other four ice patch archaeological sites are located at the northern extent of K'atieh. While K'atieh in general is recognized by Shúhtagot'ine Elders as an area rich in resources, the northern end of the flats contains a wetland complex that, like O'Grady Lake, attracts moose and waterfowl activity in the summer and fall (EBA Engineering Consultants Ltd., 2009). This area is also traversed by a major traditional trail leading to Macmillan Pass, an important route across the continental divide. Very little archaeological work has been conducted in the Northwest Territories portion of the pass, but Greer's (1982) efforts to survey the Yukon side of the pass indicated precontact use of this area. Our working hypothesis is that hunting on ice patches was part of a broader-spectrum summer subsistence economy focused on K'atieh, and that hunters tended to target ice patches near other subsistence locations in this area, such as O'Grady Lake. Other researchers report similar findings: the ice patches used by precontact hunters tend to be located near other important resource extraction areas and travel corridors, particularly fish lakes with evidence of precontact use (Hare et al., 2004; VanderHoek et al., 2007b; Greer and Strand, 2012).

Situating ice patch hunting within a broader context of land use provides an unprecedented avenue for exploring the technological organization of alpine hunter-gatherers. Studies of technological organization in North America have tended to focus on lithic technology (particularly bifaces), paying little attention to organic technologies or the organic components of tools (see LeBlanc, 2009 for discussion). In most cases, this focus is due to the poor preservation of most archaeological contexts. Yet, as Keeley (1982:800) points out, the handles or shafts of tools typically require a much longer time to manufacture than the flaked stone components. This observation leads him to suggest that "the former would be regarded as especially valuable, and therefore highly curated and carefully conserved, while the hafted tool would be replaced several times during the use-life of the haft." Detailed analysis of arrow shafts from ice patches in Yukon and the Northwest

Territories show that the wood used to manufacture these shafts was carefully selected for several attributes (Alix et al., 2012). Studies of this kind will allow archaeologists to build rich life histories for the well-preserved hunting artifacts lost or discarded at ice patch kill sites, which will illuminate patterns in raw material procurement, manufacture, repair, and recycling. These data, we expect, will contribute to our understanding of how alpine hunter-gatherers organized their technologies to take advantage of the resources offered by subarctic alpine environments.

SUMMARY AND CONCLUSION

The results presented in this paper show that both permanent and intermittent ice patches in the Selwyn Mountains are repositories of well-preserved archaeological artifacts and biological specimens. Our modeling and survey efforts resulted in the discovery in our study area of eight ice patch archaeological sites, which collectively have provided well-preserved examples of throwing-dart, bow-and-arrow, and snare technologies, as well as abundant faunal specimens. Ice patch archaeology is expanding our understanding of animal/human interactions in the Selwyn Mountains and providing a more complete picture of seasonal subsistence patterns. The work of Galloway et al. (2012) showing that paleoenvironmental conditions changed very little over the last five millennia, as well as that of Meulendyk et al. (2012) demonstrating the longevity and long-term stability of ice patches, and that of Letts et al. (2012) demonstrating genetic continuity in the Redstone caribou population over the same period, suggest that late summer ice patch hunting was a relatively stable resource that hunters could rely on when living in or travelling through the K'atieh region. Such resource stability and predictability (rare in subarctic environments) and the unique preservation environment created by the ice patches have produced rich archaeological sites.

Yet, despite their stability in past millennia, these ice patches are now experiencing dramatic change. Since 2005, we have seen several ice patches melt away entirely, and though our research did not address the question of global warming directly, this warming appears to be the likely cause of the change. Longitudinal data showing degradation of ice mass and warming of permafrost have been well documented in recent years (Rignot and Thomas, 2002; Lawrence et al., 2008; Rignot et al., 2008; Zemp et al., 2009), suggesting that the earth's cryosphere is changing at an increasingly rapid pace. The impact on ice patch archaeology will be great as this resource rapidly melts over the coming years. As a result, our research program has shifted to a monitoring program: we will revisit ice patches in the Selwyn Mountains to continue collecting important artifacts as they are revealed by melting ice.

As noted above, during the summer of 2010 we witnessed caribou bedding down in wet dung where ice had previously existed. The albedo of dung and ice are dramatically different, and eventually the dung would warm to a point where it no longer provided a cooling environment for the caribou. As more and more ice melts, the capacity of caribou to escape warming summer temperatures decreases, leading them to seek higher and potentially more dangerous snow and ice. The most southern mountain caribou herds are experiencing dramatic drops in population numbers and even extirpation in some areas (Apps and McLellan, 2006; Wittmer et al., 2007; Hebblewhite et al., 2010; Serrouya and Wittmer, 2010), which may be linked to stresses similar to those being experienced in the Selwyn and Mackenzie Mountains. These facts suggest that more research is needed to document the ecology of northern mountain caribou before dramatic changes in local environmental conditions affect these populations.

For archaeologists, climate-induced impacts on the archaeological record of the terrestrial cryosphere will escalate as global warming advances (Dixon et al., 2005; Grosjean et al., 2007; Egloff, 2008), requiring urgent action to ensure that significant heritage resources are not lost. Melting permafrost, disappearing alpine ice, and rising sea levels, coupled with catastrophic erosion events, have the potential to affect a significant portion of the extant archaeology of Arctic and Subarctic regions of the circumpolar North. The potential losses include not only rare organic archaeological remains, but also the contextual information lost when entire sites disappear in catastrophic erosion events. As these sites are frequently located in remote areas, preserving them requires the development of predictive tools (cf. Dixon et al., 2005) and lengthy and costly fieldwork commitments. Though the costs of this kind of fieldwork are high, the benefits are significant, leading to an increased understanding of the past.

ACKNOWLEDGEMENTS

As with any project of this scale there are numerous collaborators to thank for their significant efforts. We would like to acknowledge the funding support received from Canada's commitment to the International Polar Year (grant CC018 to T.D. Andrews). Additional funding came from the Government of the Northwest Territories and our community partner, the Tulita Dene Band. Logistic support for the 2010 season was provided by the Polar Continental Shelf Project. We would also like to thank the Shúhtagot'ine Elders of Tulita, the Tulita Dene Band, and the Tulita District Land Corporation for their unflagging support of the work. A number of individuals assisted with GIS and GPS applications, and we would like to thank Miles Davis, Dana Lampi, Marcella Snijders, Jennifer Bailey, Joyce de Dios, Amy Barker, and Dave Taylor. Cindy Squires-Taylor developed the Landsat image analysis protocol. Rae Braden, a Yellowknife artist, provided the artifact illustrations, and Paul Matheus (Whitehorse) and Tatiana Nomokonova (University of Alberta) undertook the faunal analysis. Claire Alix analyzed the wooden artifacts; her reconstruction of the willow bow—collected in 15 fragments—was inspiring. Many of our PWNHC colleagues assisted with aspects of the project, and we would particularly like to thank Rose Scott (conservation), Shelley Crouch (logistics, permits, and travel arrangements), and Susan Irving (collections management). Greg Hare willingly provided information on Yukon ice patches. In Norman Wells, Keith Hickling, Jason Salter, Alasdair Veitch, and Richard Popko (all with the Department of Environment and Natural Resources, Government of the Northwest Territories) provided much-needed logistic support, and we are grateful for their kind efforts. Guy Thibault added much to our field programs in 2005 and 2009. We are grateful for the critical commentary of Ingrid Kritsch, Karin Clark, Marty Magne, Jennifer Galloway, Richard Popko, Shelley Crouch, Sarah Bannon, and three anonymous reviewers, who read earlier versions of this paper.

REFERENCES

Alix, C. 2008. Wood identifications of artifacts from the NWT Ice Patches Project. Dendroarch report # 2008-3. Unpubl. ms. Available at the Prince of Wales Northern Heritage Centre, PO Box 1320, Yellowknife, Northwest Territories X1A 2L9.

———. 2009. Wood identifications of artifacts from the NWT Ice Patches Project. Dendroarch report # 2009-02. Unpubl. ms. Available at the Prince of Wales Northern Heritage Centre, PO Box 1320, Yellowknife, Northwest Territories X1A 2L9.

Alix, C., Hare, P.G., Andrews, T.D., and MacKay, G. 2012. A thousand years of lost hunting arrows: Wood analysis of ice patch remains in northwestern Canada. Arctic 65(Suppl. 1): 95 – 117.

Anderson, J.R., and Nilssen, A.C. 1998. Do reindeer aggregate on snow patches to reduce harassment by parasitic flies or to thermoregulate? Rangifer 18(1):3 – 17.

Andrews, T.D., and Zoe, J.B. 1997. The Idaa trail: Archaeology and the Dogrib cultural landscape, Northwest Territories, Canada. In: Nicholas, G.P., and Andrews, T.D., eds. At a crossroads: Archaeology and First Peoples in Canada. Burnaby, British Columbia: Archaeology Press, Simon Fraser University. 160 – 177.

Andrews, T.D., MacKay, G., Andrew, L., Stephenson, W., Barker, A., Alix, C., and the Shúhtagot'ine Elders of Tulita. 2012. Alpine ice patches and Shúhtagot'ine land use in the Mackenzie and Selwyn Mountains, Northwest Territories, Canada. Arctic 65(Suppl. 1):22 – 42.

Apps, C.D., and McLellan, B.N. 2006. Factors influencing the dispersion and fragmentation of endangered mountain caribou populations. Biological Conservation 130:84 – 97, doi:10.1016/j.biocon.2005.12.004.

Blehr, O. 1990. Communal hunting as a prerequisite for caribou (wild reindeer) as a human resource. In: Davis, L.B., and Reeves, B.O.K., eds. Hunters of the recent past. London: Unwin Hyman. 304 – 326.

Callanan, M. 2010. Northern snow patch archaeology. In: Westerdahl, C., ed. A circumpolar reappraisal: The legacy of Gutorm Gjessing (1906 – 1979). BAR International Series 2154. Oxford: Archaeopress. 43 – 54.

———. 2012. Central Norwegian snow patch archaeology: Patterns past and present. Arctic 65(Suppl. 1):178 – 188.

Cooper, J.M. 1978. Snares, deadfalls, and other traps of the Northern Algonquians and Northern Athapaskans. New York: AMS Press.

Creighton, T.B. 2006. Predicting mountain woodland caribou habitat in the Mackenzie and Selwyn Mountains through correlation of ARGOS and collar locations and MODIS spectral reflectance. MSc thesis, University of London. 112 p.

Dixon, E.J., Manley, W.F., and Lee, C.M. 2005. The emerging archaeology of glaciers and ice patches: Examples from Alaska's Wrangell–St. Elias National Park and Preserve. American Antiquity 70(1):129–143.

Dove, C.J., Hare, P.G., and Heacker, M. 2005. Identification of ancient feather fragments found in melting alpine ice patches in southern Yukon. Arctic 58(1):38 – 43.

EBA Engineering Consultants Ltd. 2009. Phase II ecological assessment: Shúhtagot'iné Néné Candidate Protected Area, Northwest Territories. Yellowknife: EBA Engineering Consultants Ltd.

Egloff, B. 2008. Archaeological heritage management, climate change and world heritage in the 21st century. In: Petzet, M., and Ziesemer, J., eds. Heritage at risk: ICOMOS World Report 2006/2007 on monuments and sites in danger. Altenburg: International Council on Monuments and Sites – E. Reinhold Verlag. 200 – 202. http://www.international.icomos.org/risk/index.html.

Environment Canada. 2011. Canadian climate normals or averages 1971 – 2000. http://climate.weatheroffice.gc.ca/climate_normals/index_e.html.

Farbregd, O. 2009. Archery history from ancient snow and ice. In: Brattli, T., ed. The 58th International Sachsensymposium, 1–5 September 2007. Vitark 7, Acta Archaeologica Nidrosiensia. Trondheim, Norway: Tapir Akademisk Forlag. 157–170.

Farnell, R., Hare, P.G., Blake, E., Bowyer, V., Schweger, C., Greer, S., and Gotthardt, R. 2004. Multidisciplinary investigations of alpine ice patches in southwest Yukon, Canada: Paleoenvironmental and paleobiological investigations. Arctic 57(3):247 – 259.

Fischer, A., Vemming Hansen, P., and Rasmussen, P. 1984. Macro and micro wear traces on lithic projectile points: Experimental results and prehistoric examples. Journal of Danish Archaeology 3:19 – 46.

Galloway, J.M., Adamczewski, J., Schock, D.M., Andrews, T.D., MacKay, G., Bowyer, V.E., Meulendyk, T., Moorman, B.J., and Kutz, S.J. 2012. Diet and habitat of mountain woodland caribou inferred from dung preserved in 5000-year-old alpine ice in the Selwyn Mountains, Northwest Territories, Canada. Arctic 65(Suppl. 1):59 – 79.

Gillespie, B.C. 1981. Mountain Indians. In: Helm, J., ed. Handbook of North American Indians: Vol. 6, Subarctic. Washington, D.C.: Smithsonian Institution. 326 – 337.

Green, K., and Pickering, C. 2009. The decline of snowpatches in the Snowy Mountains of Australia: Importance of climate warming, variable snow, and wind. Arctic, Antarctic, and Alpine Research 41(2):212 – 218, doi:10.1657/1938-4246-41.2.212.

Greer, S. 1982. An introduction to the archaeology of the Macmillan Pass – north Canol Road area, Yukon Territory. Unpubl. ms. Available at the Canadian Museum of Civilization, PO Box 3100, Station B, Hull, Quebec J8X 4H2.

Greer, S., and Strand, D. 2012. Cultural landscapes, past and present, and the South Yukon ice patches. Arctic 65(Suppl. 1): 136 – 152.

Grosjean, M., Suter, P.J., Trachsel, M., and Wanner, H. 2007. Ice-borne prehistoric finds in the Swiss Alps reflect Holocene glacier fluctuations. Journal of Quaternary Science 22(3): 203 – 207.

Hafner, A. 2012. Archaeology discoveries on Schnidejoch and at other ice sites in the European Alps. Arctic 65(Suppl. 1): 189 – 202.

Hanks, C.C. 1997. Ancient knowledge of ancient sites: Tracing Dene identity from the late Pleistocene and Holocene. In: Nicholas, G.P., and Andrews, T.D., eds. At a crossroads: Archaeology and First Peoples in Canada. Burnaby, British Columbia: Archaeology Press, Simon Fraser University. 178 – 189.

Hanks, C.C., and Winter, B.J. 1986. Local knowledge and ethnoarchaeology: An approach to Dene settlement systems. Current Anthropology 27(3):272 – 275.

Hare, P.G., Greer, S., Gotthardt, R., Farnell, R., Bowyer, V., Schweger, C., and Strand, D. 2004. Ethnographic and archaeological investigations of alpine ice patches in southwest Yukon, Canada. Arctic 57(3):260 – 272.

Hare, P.G., Thomas, C.D., Topper, T.N., and Gotthardt, R.M. 2012. The archaeology of Yukon ice patches: New artifacts, observations, and insights. Arctic 65(Suppl. 1):118 – 135.

Hebblewhite, M., White, C., and Musiani, M. 2010. Revisiting extinction in national parks: Mountain caribou in Banff. Conservation Biology 24(1):341 – 344, doi:10.1111/j.1523-1739. 2009.01343.x.

Helwig, K., Monahan, V., and Poulin, J. 2008. The identification of hafting adhesive on a slotted antler point from a southwest Yukon ice patch. American Antiquity 73(2):279 – 288.

Ingold, T. 1980. Hunters, pastoralists, and ranchers: Reindeer economies and their transformations. Cambridge: Cambridge University Press.

Ion, P.G., and Kershaw, G.P. 1989. The selection of snowpatches as relief habitat by woodland caribou (*Rangifer tarandus caribou*), Macmillan Pass, Selwyn/Mackenzie Mountains, N.W.T, Canada. Arctic and Alpine Research 21(2):203 – 211.

Keeley, L.H. 1982. Hafting and retooling: Effects on the archaeological record. American Antiquity 47(4):798 – 809.

Kuhn, T.S., McFarlane, K.A., Groves, P., Mooers, A.Ø., and Shapiro, B. 2010. Modern and ancient DNA reveal recent partial replacement of caribou in the southwest Yukon. Molecular Ecology 19(7):1312 – 1323, doi:10.1111/j.1365-294X. 2010.04565.x.

Kuzyk, G.W., Russell, D.E., Farnell, R.S., Gotthardt, R.M., Hare, P.G., and Blake, E. 1999. In pursuit of prehistoric caribou on Thandlät, southern Yukon. Arctic 52(2):214 – 219.

Lawrence, D.M., Slater, A.G., Tomas, R.A., Holland, M.M., and Deser, C. 2008. Accelerated Arctic land warming and permafrost degradation during rapid sea ice loss. Geophysical Research Letters 35, L11506, doi:10.1029/2008GL033985.

Le Blanc, R.J. 2009. Some implications of high-latitude osseous technologies for forager technological organization. In: Keenlyside, D.L., and Pilon, J.-L., eds. Painting the past with a broad brush: Papers in honour of James Valliere Wright. Mercury Series, Archaeology Paper 170. Hull, Quebec: Canadian Museum of Civilization. 529 – 554.

Lee, C.M. 2012. Withering snow and ice in the mid-latitudes: A new archaeological and paleobiological record for the Rocky Mountain region. Arctic 65(Suppl. 1):165 – 177.

Letts, B., Fulton, T.L., Stiller, M., Andrews, T.D., MacKay, G., Popko, R., and Shapiro, B. 2012. Ancient DNA reveals genetic continuity in mountain woodland caribou of the Mackenzie and Selwyn Mountains, Northwest Territories, Canada. Arctic 65(Suppl. 1):80 – 94.

MacDonald, G.M. 1983. Holocene vegetation history of the upper Natla River area, Northwest Territories, Canada. Arctic and Alpine Research 15(2):169 – 180.

Matheus, P. 2008. Northwest Territories ice patch faunal analysis: Narrative report for faunal material collected 2005 – 2007. Unpubl. ms. Available at the Prince of Wales Northern Heritage Centre, PO Box 1320, Yellowknife, Northwest Territories X1A 2L9.

McClellan, C. 2001. My old people say: An ethnographic survey of southern Yukon Territory. Part 1. Mercury Series, Canadian Ethnology Service Paper 137. Hull, Quebec: Canadian Museum of Civilization.

McClellan, C., and Denniston, G. 1981. Environment and culture in the Cordillera. In: Helm, J., ed. Handbook of North American Indians: Vol. 6, Subarctic. Washington, D.C.: Smithsonian Institution. 372 – 386.

Meulendyk, T., Moorman, B.J., Andrews, T.D., and MacKay, G. 2012. Morphology and development of ice patches in Northwest Territories, Canada. Arctic 65(Suppl. 1):43 – 58.

Nomokonova, T. 2009. Report on the analysis of faunal material collected in August 2008. Unpubl. ms. Available at the Prince of Wales Northern Heritage Centre, PO Box 1320, Yellowknife, Northwest Territories X1A 2L9.

NWT Geoscience Office, 2009. Selwyn-Mackenzie Shale Basins Project. http://www.nwtgeoscience.ca/minerals/mackenzie_selwyn.html.

Odell, G.H., and Cowan, F. 1986. Experiments with spears and arrows on animal targets. Journal of Field Archaeology 13(2):195 – 212.

Osgood, C. 1970. Ingalik material culture. Yale University Publications in Anthropology 22. New Haven, Connecticut: Human Relations Area Files Press.

Pojar, J. 1996. Environment and biogeography of the western boreal forest. The Forestry Chronicle 72(1):51 – 58.

Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., et al. 2009. Intcal09 and Marine09 radiocarbon age calibration curves, 0 – 50,000 years cal BP. Radiocarbon 51(4):1111 – 1150.

Rignot, E., and Thomas, R.H. 2002. Mass balance of polar ice sheets. Science 297:1502–1506, doi:10.1126/science.1073888.

Rignot, E., Bamber, J.L., Van den Broeke, M.R., Davis, C., Li, Y., Van de Berg, J., and Van Meijgaard, E. 2008. Recent Antarctic ice mass loss from radar interferometry and regional climate modelling. Nature Geoscience 1:106 – 110, doi:10.1038/ngeo102.

Schlanger, S.H. 1992. Recognizing persistent places in Anasazi settlement systems. In: Rossignol, J., and Wandsnider, L., eds. Space, time, and archaeological landscapes. New York: Plenum Press. 91 – 112.

Serrouya, R., and Wittmer, H.U., eds. 2010. Imminent extinctions of woodland caribou from national parks. Conservation Biology 24(2):363 – 364, doi:10.1111/j.1523-1739.2010.01454.x.

Stuiver, M., Reimer, P.J., and Reimer, R.W. 2005. CALIB radiocarbon calibration, Version 6.0: Marine reservoir correction database. http://calib.qub.ac.uk/calib/.

VanderHoek, R., Tedor, R.M., and McMahan, J.D. 2007a. Cultural materials recovered from ice patches in the Denali Highway region, central Alaska, 2003 – 2005. Alaska Journal of Anthropology 5(2):185 – 200.

VanderHoek, R., Wygal, B., Tedor, R.M., and Holmes, C.E. 2007b. Ice patch research and monitoring in the Denali Highway region, central Alaska, 2003 – 2005. Alaska Journal of Anthropology 5(2):67 – 86.

VanderHoek, R., Dixon, E.J., Jarman, N.L., and Tedor, R.M. 2012. Ice patch archeology in Alaska: 2000 – 10. Arctic 65(Suppl. 1): 153 – 164.

Weaver, J.L. 2006. Big animals and small parks: Implications of wildlife distribution and movements for expansion of Nahanni National Park Reserve. Conservation Report No. 1. Toronto: Wildlife Conservation Society Canada.

Wittmer, H.U., McLellan, B.N., Serrouya, R., and Apps, C.D. 2007. Changes in landscape composition influence the decline of a threatened woodland caribou population. Journal of Animal Ecology 76:568 – 579.

Zemp, M., Hoelzle, M., and Haeberli, W. 2009. Six decades of glacier mass-balance observations: A review of the worldwide monitoring network. Annals of Glaciology 50:101 – 111.