Overview of Ice Patch Archaeology

As the Earth’s climate warms, archaeological and paleontological materials are being discovered at areas of melting perennial snow and ice drifts, or “ice patches,” in high latitude and high altitude mountain areas (Hare et al. 2004; Dixon et al. 2005; Grosjean et al. 2007), including in the Greater Yellowstone Ecosystem (GYE; Lee 2008a, 2008b, 2009, 2010a, in press). Ice patches characteristically exhibit little internal deformation and/or movement, and consequently they can contain ancient ice that, unlike glaciers, is kinetically stable. Freezing retards the decay of organic material, and in some instances these features have preserved otherwise perishable hunting gear and associated equipment in the context in which it functioned for millennia (Lee 2010a, in press).

Although cultural material has been discovered in association with ice patches for at least the past century (Keddie and Nelson 2005; Farbregd 1972), the discovery of Otzi, the “Ice Man,” and associated artifacts by hikers in 1991 (Spindler 1994) arguably marks the beginning of a modern era of ice patch archaeology. Shortly thereafter in 1993, a significant but essentially unreported artifact was identified by hikers in Olympic National Park: remnant fragments of a loose-weave burden basket melting out of a perennial snowfield within a hundred meters of a previously recorded lithic scatter (D. Conca, pers. comm. 2005; National Park Service 2006). The largest of the basket fragment measures ca. 21 x 28 centimeters (cm; 8.5 x 11 inches), and a sample of the basket was radiocarbon dated to ca. 2,900 years Before Present (BP; National Park Service 1999, 2006). The burden basket may have been used to pack a variety of materials, including snow from the ice patch to the nearby campsite, and may have been abandoned at the ice patch after failing.

Abstract

As the Earth’s climate warms, archaeological and paleobiological materials are being discovered in areas of melting perennial snow and ice. Although artifacts have occasionally been found in association with glaciers, in North America they have primarily been discovered in association with relatively static snow banks, or “ice patches.” Some ice patches were used prehistorically by Native Americans to hunt game animals, for example, bighorn sheep and bison that were attracted to the locations. Preserved organic artifacts that might result from such encounters include arrows, darts, sinew lashing and fletching, as well as basketry, clothing, and cordage. The stable ice in these features retards decay and has kept otherwise perishable materials suspended in virtually unaltered states for millennia. Once released from this protective environment, arrested taphonomic processes resume and organic artifacts rapidly decompose. Ice patch discoveries within the Greater Yellowstone Ecosystem (GYE) include a complete atlatl dart foreshaft, dart and arrow shaft fragments, chipped stone tools, and processed animal remains. The discoveries offer important insights into alpine paleoecology and the use of high-elevation environments by prehistoric humans. Ice patch archaeology is a nascent field in North America, and the GYE ice patches are the most intensively studied in the conterminous United States. This paper: 1) provides a review of the global state of ice patch archaeology; 2) reviews progress made in the last five years to identify and survey prospective locations in the GYE; and 3) highlights directions for building and maintaining resource awareness.
The growing database of ice patch discoveries has illuminated some interesting regional differences in the prehistoric use of the features. For example, most ice patch discoveries in North America and Norway are connected to hunting, while finds in the Alps and British Columbia are most often associated with travel and transport through mountain passes (Figure 1). Discoveries in South America are primarily related to sacred activities (Ceruti 2010). A recent master’s thesis by University of Wyoming student Rachel Reckin (2011) begins the necessary process of synthesizing the disparate data available on ice patch archaeology.

**Survey in the GYE**

Ice patches are present throughout the high-elevation areas of the GYE, with most associated archaeological sites occurring between 9,500 and 10,500 feet; however, sites have been identified as high as 11,250 feet (Figure 2). There are a variety of imperfect proxies to gauge survey conditions, including the mass balance of glaciers; however, ice patches “breathe” differently than glaciers and respond more noticeably to vagaries in the seasonal accumulation of snow and summer melting.

Several factors appear to influence an ice patch’s potential to contain archaeological material, including: 1) relative isolation of ice patches from one another, which seems to concentrate activity toward a given location; 2) proximity to lower elevation, ice patch–free country; and 3) relative ease of access (e.g., proximity to human and animal travel corridors [passes]). Depending on the degree of melt and local conditions, in some years ice patches can appear to have a black halo, particularly on their downslope sides, due to the presence of windblown and other organic material (e.g., animal feces).

The techniques used to identify permanent ice patches in the GYE (Lee 2007a, 2007b, 2007c, 2008a, 2008b) have been adapted for use elsewhere, including in Denali (Lee 2010c), Rocky Mountain (Lee 2010b), and Glacier National Parks (Kelly and Lee 2010).

The ice patch identification process involves using virtual globes (VG) and other sources of publicly available satellite and aerial imagery to scan a given area for snow and ice exhibiting the characteristics outlined above and in the introduction (Lee 2009, 2010b). VGs, such as Google Earth (earth.google.com) and NASA’s World Wind (worldwind.arc.nasa.gov) play a significant role in this endeavor, but other online utilities such as Flash Earth (flashearth.com) and proprietary imagery are often useful. VGs can easily manipulate complex geospatial data in three dimensions to maximize topographic relief and to focus on the northeast-facing exposures where ice patches persist. At a minimum, before going into the field to conduct a survey, it is advisable to examine the prospective survey area with a VG for ice patches meeting the above criteria.

After prospective locations have been identified, aerial reconnaissance of the target ice patches is conducted prior to pedestrian surveys. Aerial reconnaissance consists of late summer overflight(s) of prospective ice patches that can be used to assess melting. Ice patch archaeological sites have been identified on the Custer and Shoshone National Forests and in Yellowstone National Park (Lee et al. 2009; Lee, in press). Numerous paleobiological sites consisting...
of non-cultural, relict wood, for example, spruce (cf. Picea engelmannii) as well as animal remains, e.g., bighorn sheep (Ovis canadensis) and bison (Bison bison), have been identified in these resource areas as well as in the Gallatin National Forest. Most chronometric data for the sites, specimens and artifacts discussed are presented as radiocarbon years ($^{14}$C) before present. To preserve continuity and utility, this paper uses the radiocarbon timescale throughout in the $^{14}$C BP notation. Calibrated ages—those ages derived from comparison of $^{14}$C BP ages with calibration curves, for example, IntCal09 are identified as such by the preface “cal yr” or simply “cal.”

**Paleobiological Specimens**

Two of the first paleobiological samples encountered at a GYE ice patch consisted of tree stumps in growth position melting out of the bottom of an ice patch on Grass Mountain (Figure 3). The ice patch is above modern treeline. The trees were identified as spruce (cf. Engelmann spruce; J. Lukas, pers. comm. 2006). One of the assays returned an accelerator mass spectrometry (AMS) $^{14}$C age of 7,935 ± 15 years BP and the other returned an AMS $^{14}$C age of 7,955 ± 15 years BP. These dates are noted in Carrara (in press) as well as Lee (in press). The Holocene thermal maximum (ca. 10,000 to 8,500 cal yr BP) was as much as 6°C warmer than historic summer temperatures (Miller et al. 2005), which allowed trees to grow at this higher elevation. The trees may have met their demise during the rapid cooling that was underway by ca. 8,500 cal yr BP when their micro-environment filled in with snow. Additional discoveries of non-anthropogenic trees/wood have been made at other ice patches, including in Colorado and Wyoming (e.g., Benedict et al. 2008). A survey of dead wood above treeline on Grass Mountain reported no surface wood older than ca. 1,300 $^{14}$C years BP (A. Bunn pers. comm. 2007; Bunn et al. 2004).

**Archaeological Sites**

Inclusive of the 2010 field season, at least seven (but may be up to nine) prehistoric sites associated with melting “ice patches” have been identified in the GYE. Archaeological discoveries include sites with organic and chipped stone artifacts as well as sites with butchered animal remains exposed by melting ice.

The most remarkable and oldest artifact recovered from the GYE ice patches is a complete wooden dart foreshaft made from a birch (Betula sp.) sapling trimmed of its branches (Figure 4). A small sample of wood taken from a break in the foreshaft was AMS $^{14}$C dated to 9,230 ± 25 BP; calibrated age 10,281–10,497 cal BP (p = 1.0). The artifact is contemporary with the late Paleoindian

![Figure 2](image-url)  
*Figure 2. The area in green is a composite of contiguous high-elevation landforms and major valley systems that comprise the Greater Yellowstone Ecosystem (duplicated from Lee 2010a).*

![Figure 3](image-url)  
*Figure 3. Mike Bergstrom (USFS archaeologist) examines one of the two ca. 8 ka year-old tree bases exposed in the melting toe of the Grass Mountain ice patch. Photo by Craig Lee.*
Cody complex (ca. 9,200–8,400 \(^{14}\)C BP or 11,220–9,445 cal BP) in North American archaeology. Locally, this time period coincides with the Alder complex (Davis et al. 1989). The complete weapon was probably propelled by an atlatl, or spear thrower, which would have provided mechanical advantage by increasing the leverage of the thrower’s arm, resulting in greater projectile velocity.

Two groups of three evenly spaced lines on opposing sides of the artifact are inferred to be ownership or property marks (Lee 2010a). Ethnographic observations indicate ownership marks occur on hunting weapons designed to remain in the bodies of large game. They typically consist of simple lines and can be specific to either an individual or community. The lines on the foreshaft appear to be embossed or pressed into the wood with a ca. 1 millimeter (mm)-wide tool on the thinnest portion of the shaft near the projectile point haft. If the shaft broke off inside the animal, this portion could link the hunter with the kill.

The ability to differentiate weapons based on distinctive marks suggests other elements of these artifacts (e.g., projectile points) were not indicative of, or distinctive to, the person using the weapon (Lee 2010a). Particularly skilled individuals within a band or group may have crafted most of the technically demanding points (Lee 2010a).

**Protecting Ice Patches**

In addition to monitoring productive sites and identifying new ones, stabilization may be a realistic option for the most significant locations. Two potential stabilization techniques have been identified. Snow fences could be used to artificially bolster the amount of snow on the patch. Such fences should not be raised until after the winter cold wave has penetrated the old ice core. A second possibility is to use thermally insulating blankets similar to those used in Switzerland to preserve snow bases at ski areas.

**Building and Maintaining Resource Awareness**

The ice patch phenomenon transcends the political boundaries that divide the GYE. The goals of our ongoing work are five-fold: 1) to identify and characterize sites currently threatened by climate change that will be lost if not properly identified and recorded (protected) immediately; 2) to provide GYE unit resources managers with a report that may aid in resource management decisions; 3) to generate unparalleled scientific data regarding human adaptations in the GYE through the analysis of unique, ancient, organic artifacts; 4) to augment and correlate with regional climate studies through the analysis of ancient paleoenvironmental records, such as frozen tree stands; and 5) to promote public education through the use of student/volunteer labor and the dissemination of project results via presentations at professional meetings and publications.

Ice patch discoveries provide an amazing way to capture public interest and integrate education about archaeology, Native American cultures, and modern climate change. We are currently planning to engage a videographer to film,

**Figure 4. Dart foreshaft. Clockwise from large image: A) the complete foreshaft; B) detail of the hafting element at the tip (the probable ownership marks are visible near the bottom of the image); C) detail of animal damage (probably a trampling fracture that occurred when the artifact was saturated and partially buried in slush); D) detail of the base portion of the foreshaft. Scales in centimeters.**

Photos by Tara L. Hornung (duplicated from Lee 2010a)
edit, and produce a 15 minute Web video highlighting the critical thinking and findings of ice patch archaeology in the GYE. The engaging and informative video will serve multiple purposes. The Web link can be shared through informal partners, such as the U.S. Forest Service “Passport in Time” program as well as through Project Archaeology, which has an educational mandate to bring archaeology to middle school classrooms. The video can also be copied to DVD (or streamed) into classroom settings during the annual “Archaeology Month” (or “Archaeology Week”) in GYE and other Rocky Mountain states, and the online content will augment allied educational missions around the globe, including at Klimapark2469 in Norway (http://www.oppland.no/Klimapark2469-English) and the Kwanlin Dun Heritage Center in Yukon, Canada. Additional details about ice patch archaeology in the GYE can be found online at http://instaar.colorado.edu/ice_archaeology. “Ice Patch Archaeology” was the theme of the 2010 Montana Archeology month poster (Figure 5). Poster copies are available from Damon Murdo (dmurdo@mt.gov) at the Montana Historical Society.

Take Home Messages
The effects of climate change are tangible in northern and mid-latitude ice patches. Ice patch discoveries provide a unique way to capture public interest and to educate about other effects of global warming. The ice patch phenomenon is global and transcends the state and government boundaries that permeate the GYE. This research would benefit from supra-level organization, such as might be provided by the Greater Yellowstone Coordinating Committee (GYCC).

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Questioning Greater Yellowstone's Future
Climate, Land Use, and Invasive Species

The 10th Biennial Scientific Conference on the
Greater Yellowstone Ecosystem

Conference Proceedings
October 11–13, 2010
Mammoth Hot Springs Hotel
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Conference Mission

The mission of this conference was to generate discussion on changes in three external drivers—climate, land use, and invasive species—that could dramatically alter Greater Yellowstone’s public and private lands. This conference offered participants an opportunity to help shape this region’s future regarding key issues such as:

• How is the Greater Yellowstone climate likely to change in the near future and how do climate projections compare with historical patterns?
• What ecological changes are underway as a result of changing climate and land use, and what will be the consequences for human and natural systems?
• In what ways do increasing demands on public and private lands threaten a sustainable future?
• Which non-native species pose the greatest threat for the region and what are some of the anticipated environmental, social, economic, and human-health consequences of invasive species?
• What new administrative, technological, and scientific tools and strategies are required to address the challenges of changing climate and land use and the threats from invasive species?
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