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The Archaeology and Paleoecology of Alpine Ice Patches: A Global Perspective

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At a recent conference called *Frozen Pasts*, held in Trondheim, Norway, in October 2010, presentations by researchers from five continents addressed a broad sweep of human history and culture, including the archaeological remains of caribou or reindeer hunting preserved in ice patches in North America and Norway; stratified Paleo-Eskimo middens in Greenland permafrost; First World War archaeological remains melting from snow patches in the Italian Alps; the conservation of Scott's hut in Antarctica; permafrost burials of Iron Age Scythians in the Altai Mountains; and the discovery of Inca mummies in the Andes of Argentina. Linked only by their setting in the cryosphere, that part of the Earth's surface where water is frozen for at least part of the year in the form of snow, ice, or permafrost (Slaymaker and Kelly, 2007), the papers also served to catalogue the impact that global warming is having on archaeological remains. Permafrost, alpine snow patches, glaciers, and other components of the cryosphere are melting at alarming rates. The impact of these changes—altered regional climate patterns, rising sea levels, and catastrophic slope collapses from thawing permafrost, among others—are putting heritage resources at risk, requiring urgent action from archaeologists and other heritage specialists. By sharing their experiences at conferences like *Frozen Pasts*, archaeologists and other researchers are cataloguing these impacts while working to define a new sub-discipline: archaeology of the terrestrial cryosphere.

It is in this spirit that we present this special supplement of the journal *Arctic*, which brings together 12 articles in the emerging field of alpine ice patch archaeology from North America and Europe. Linked by their association with either caribou or reindeer hunting or human travel in alpine environments, these articles provide a fascinating perspective on the cryogenically preserved artifacts and biological specimens being revealed by the melting of perennial snow and ice in high alpine settings.

The first six papers present the findings of the Northwest Territories (NWT) Ice Patch Study, an International Polar Year (IPY) Project funded by the Government of Canada between 2006 and 2010. IPY is the largest-ever program of scientific research focused on the Arctic and Antarctic regions (Government of Canada, 2011), and its results are leading to significant advances in our understanding of the effects of climate change on the circumpolar world and its people. The Government of Canada's IPY Program envisioned an intense "pulse" of multidisciplinary research focused on two main themes: 1) climate change impacts and adaptation and 2) the health and well-being of northern Canadians. The research design advanced by the IPY Program encouraged partnerships across disciplines in order to investigate these themes in their full complexity. This approach is reflected in these papers, which explore the human, ecological, and physical dimensions of alpine ice patches in the Selwyn Mountains of the NWT.

In the first paper of the volume, Andrews et al. report on the results of archaeological investigations of alpine ice patches in the Selwyn Mountains. Well-preserved hunting weapons and biological specimens collected from ice patches in this region provide a long-term record of caribou hunting by precontact peoples. The paper offers a potential contribution to future archaeological work on ice patch sites in circumpolar alpine regions through its description of methods—a combination of remote sensing and other modeling criteria—used to detect alpine areas in the NWT with the potential for ice patch archaeological sites.

In the second paper, Andrews et al. describe the important role that the traditional knowledge of Shúhtagot'ine Elders played in the interpretation of ice patch archaeological sites and artifacts. They contextualize their discussion with a description of the NWT Ice Patch Study outreach program, which provided several forums for sharing knowledge throughout the project. As part of all IPY-funded projects in Canada, outreach programs fostered meaningful community involvement across the Canadian North and will surely be remembered as one of IPY's greatest legacies. Conducted in partnership with the Tulita Dene Band and Shúhtagot'ine Elders, the NWT Ice Patch Study included an ambitious community outreach program that brought educational products and benefits to all participants.

The next three papers explore the physical and ecological dimensions of alpine ice patches in the Selwyn Mountains. Meulendyk et al. use ground-penetrating radar and ice coring to determine the internal structure of two ice patches. They develop a model of ice patch formation and discuss potential for the use of ice patches to reconstruct regional paleoenvironmental conditions. The fact that ice patches are perennially frozen and are relatively static features (i.e., compared to glaciers) accounts for their ability to preserve even the most fragile components of ancient hunting weapons. Galloway et al. evaluate the use of caribou dung preserved in alpine ice patches to reconstruct paleoecological conditions in alpine environments. Their analysis of pollen and spores trapped in caribou dung indicates that vegetation communities in the vicinity of the ice patches have remained largely unchanged for the last 5000 years. In a similar manner, plant fragments document the

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stability of summer caribou diet over this timeframe. Letts et al. use ancient DNA techniques to investigate the population dynamics of caribou in the Selwyn and Mackenzie Mountains. Comparing mitochondrial DNA sequences from ancient bones, teeth, and antlers preserved in alpine ice patches with those of modern caribou, they show that the resident Redstone population of mountain caribou has been "robust to environmental change over the past 4000 years" (p. 92). Taken together, Galloway et al. and Letts et al. provide an important baseline for evaluating changes to mountain caribou diet and health that could occur as the global climate continues to warm.

An important goal of the IPY program, one that is reflected in its international scope, was to examine ecological and cultural patterns and processes at regional scales. This theme is exemplified in Alix et al.'s paper, which traces spatial and temporal patterns in the attributes of arrows (particularly the wood shafts) collected from ice patches in the Yukon and the Northwest Territories. Interestingly, the authors demonstrate that two main types of arrows co-existed across space and time in this region.

North American ice patch archaeology began in 1997 with the discovery of a fragment of a wood atlatl dart in southern Yukon. This exciting find stimulated projects in Alaska, the northern Rockies of the continental United States, the NWT, and the Swiss Alps. The Yukon discovery also helped provide a common link between ancient caribou and reindeer hunters on two continents by bringing attention to decades of ice patch archaeological research in Norway, undertaken quietly and without much international fanfare by Trondheim-based archaeologist Oddmunn Farbregd (see Callanan, 2010 for a succinct history of this important research). We invited archaeologists from the Yukon, the United States, Norway, and the Swiss Alps to contribute overviews of their work to this volume in order to provide global context for the emerging archaeological record of alpine ice patches in other areas of the alpine cryosphere.

Hare et al. provide an update on the results of ice patch research in the Yukon Territory since 2004 – approximately eight years after the publication of what will likely be recognized as the seminal paper in North American ice patch archaeology (Hare et al., 2004). With datasets now comprising 207 artifacts, more than 1700 faunal skeletal remains, and more than 200 radiocarbon dates, Hare et al. note: "One of the challenges in reporting on the results of the Yukon Ice Patch Project is to move beyond simply describing the objects that have been recovered to interpreting trends through time" (p. 130). Their paper meets this challenge, using innovative statistical techniques to delineate long-term trends in both human land-use patterns and caribou abundance in the southern Yukon.

Greer and Strand examine the social and cultural context of ice patch research in southern Yukon, outlining the important role that Yukon First Nations are playing in this project. Like Andrews et al., they highlight the contribution of Aboriginal traditional knowledge to ice patch research and the value of designing research programs with strong community outreach initiatives.

VanderHoek et al. show that hunting caribou on ice patches has been an important part of subsistence practices in Alaska for at least 4000 years. A key point in their paper—one that is echoed in several other contributions—is that while caribou hunting was perhaps the main reason for visiting ice patches, these areas also provided a wider range of resource gathering opportunities, such as harvesting birds, small game, and berries.

Craig Lee reports on his efforts to characterize ice patch archaeological sites in the Greater Yellowstone Area of Montana and Wyoming, where perennial ice patches exist at high elevations, typically more than 3000 m above sea level (asl). Precontact hunters in Montana and Wyoming, like those in the subarctic alpine areas of North America, appear to have targeted ice patches to hunt large mammals, principally bighorn sheep and bison.

Martin Callanan's contribution is the first of two papers to provide overviews of ice patch research projects underway in Europe. Callanan chronicles the long history of ice patch research in Norway, where artifacts—principally arrows used for hunting wild reindeer—have been collected at ice patches since 1914. Albert Hafner reports on the results of ice patch research on the Schnidejoch in the Bernese Alps, where an ice patch has produced an impressive 6000-year record of well-preserved artifacts spanning the Neolithic, Early Bronze Age, Iron Age, Roman period, and Middle Ages. In contrast to most areas described in this volume, where caribou or reindeer hunting was the main reason for visiting alpine ice patches, on the Schnidejoch the artifacts recovered appear to have been left by people travelling through an important mountain pass.

Several important themes emerge throughout the 12 articles comprising this volume. First, melting ice patches are revealing artifacts and technologies rarely found in subarctic archaeological contexts. In this regard, archaeologist and former museum director Robert R. Janes (2009:5) mused about the poor state of preservation in archaeological contexts in the western portion of the boreal forest, one of the world's largest forests, which is home to Athapaskan-speakers, whose ancestors created the tools found in the ice patch sites in Alaska, Yukon, and the NWT. He was disappointed to find that in a major museum exhibit—the 1974 "Athapaskans: Strangers of the North," which brought together objects from two of the world's best collections from this region—only 21% of the objects contained wooden components. In contrast, well over 95% of the objects recovered from ice patch contexts in the same region have wooden components, and these fragile artifacts underscore the value and importance of the ice patch sites. Well-preserved complex implements made from stone, bone, antler, wood, sinew, and feathers, sometimes with preserved pigments and hafting adhesives, are providing unique opportunities to study the manufacture and use of implements and technologies rarely seen in the archaeological or ethnographic record.

Second, in several areas described in this volume, ice patch archaeology is allowing archaeologists to integrate high alpine areas into models of human land use, resulting in a richer understanding of past adaptive strategies. Hare et al., for example, note that before ice patch research began, only two archaeological sites with elevation above 1250 m asl had been recorded in the Yukon Territory. In a similar manner, Albert Hafner notes that before the discovery of the "Iceman" in the Ötzal Alps in 1991, archaeologists assumed that alpine regions above the tree line were little used during the Neolithic period.

Third, the phenomenon of ice patch archaeology provides an opportunity to reinterpret other archaeologies. For example, archaeologists working in Maine, employing paleoenvironmental and geographic models in association with site distribution and toolstone occurrence data, suggest that Paleo-Indians followed migrating caribou using ice patch hunting techniques in upland areas (Pelletier and Robinson, 2005). Great potential exists to model paleoclimate, topography, and seasonal snow conditions in Paleolithic and Mesolithic Europe to search for or reinterpret sites on the Central Massif in France, the Pyrenees, or other mountainous or upland regions throughout Eurasia. These same techniques could be applied to Paleo-Indian occupations along the Niagara Peninsula in Ontario, Canada, or to other high-latitude or upland regions in North America.

Finally, it is clear that ice patch archaeological sites throughout the circumpolar North are at great risk of impact from warming climates, and this is, perhaps, where our projects best articulate with the Government of Canada's main IPY research themes. Climate-induced impacts to archaeological and paleontological sites in the North are beginning to reach a critical threshold. Rising sea levels and intense coastal storms are causing massive erosion of coastal archaeological sites, and thawing permafrost is exposing organic artifacts preserved in frozen sites to microbial activity, or destroying their context through thaw slumping processes. Alpine ice patches are the new "poster-child" for climate-induced impacts to archaeological sites in the North. For example, Figure 1 shows the dramatic melt of an ice patch in the Selwyn Mountains, Northwest Territories, between 2009 and 2011. Caribou fecal matter collected in 2007 from the lowest of several dung-rich strata in an ice core from this patch was dated to 3270 ± 40 BP, indicating the long-term stability of this feature. It is clear that this ice patch—now little more than a thick smear of caribou dung across the mountainside—has melted more in the last few years than it has in millennia. Distinct layers of caribou dung preserved in the ice, which offer a rare glimpse at caribou food habit patterns over time (Galloway et al.), have collapsed into a "dung palimpsest" of far less analytical value. The organic components of artifacts exposed by melting ice patches, if not collected, will almost certainly dry, crack, and blow away in a matter of years.

Since these repositories of well-preserved organic artifacts are continuing to melt throughout the Northern Hemisphere, exposing fragile remains to certain loss, similar work must be initiated urgently in other alpine regions where the chance exists of finding remaining ice associated with the altitudinal migration of caribou and reindeer, bighorn sheep, bison, and rich hunting traditions. In Canada, for example, the Rocky Mountains straddling the British Columbia/Alberta borders constitute one such prime location, though much of northern British Columbia also has appropriate mountain settings. Farther north, the semi-permanent ice patches on Ellesmere and Baffin Islands and other islands in the Canadian High Arctic may also hold potential, as might the Torngat Mountains in Labrador. Several papers in this volume describe remote-sensing methods that can be used to begin looking for perennial ice patches in these areas. For example, Craig Lee makes effective use of publicly available virtual globes, such as Google Earth and NASA's World Wind, to find ice patches in the Greater Yellowstone Area, and Andrews et al. use location data from modern caribou with satellite collars to pinpoint high alpine areas used by caribou in the summers. These methods may be useful in other areas where similar data are available.

What do climate change impacts to ice patches mean for the caribou that use them? Research in both Scandinavia (Anderson and Nilssen, 1998) and Canada (Ion and Kershaw, 1989) demonstrates that reindeer and caribou use alpine ice patches to cool down on warm summer days and to seek relief from parasitic flies. Indeed, it is this behavior that led ancient hunters to ice patches in the first place. In 2010, during summer fieldwork in the Selwyn Mountains, we witnessed mountain caribou bedding down in dung where ice patches had existed until recently, suggesting that caribou are habituated not only to ice patches, but also to their specific locations, whether ice remains or not. As these summer alpine patches continue to melt and disappear, what long-term impacts might this have on northern mountain caribou or wild reindeer populations? Importantly, how might changes in mountain caribou populations affect the Aboriginal societies that hunt them? Caribou population changes in Canada have been dramatic in recent years (Festa-Bianchet et al., 2011), and blame is attributed to a complex set of stressors, only some of which can be linked to climate change. Human land-use changes, habitat fragmentation, lack of aggressive management actions, and in some cases, catastrophic events, such as the avalanche that killed the last five mountain caribou in Banff National Park in April 2009 (Hebblewhite et al., 2010), have all led to declining caribou populations. However, climate-induced habitat changes may also affect caribou energetic costs, resulting in changes to vital rates (e.g., birth, death, and fertility). As the papers in this volume demonstrate, alpine ice patches can provide important baseline data on caribou population genetics and health that can be applied in future research and management. Further research is urgently required to understand ecological change and the resulting impact on heritage resources associated with these significant habitats.

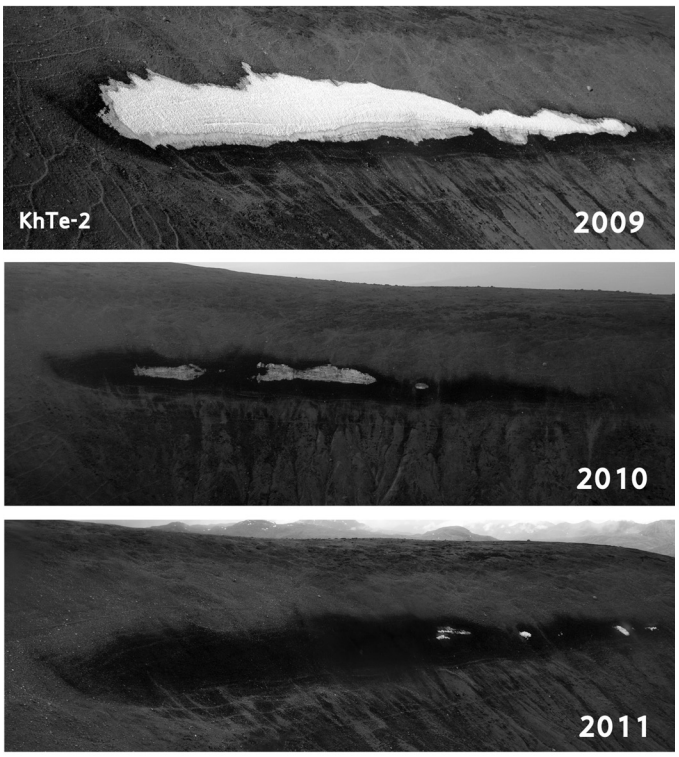

FIG. 1. Ice patch archaeological site KhTe-2, located in the Selwyn Mountains, Northwest Territories, showing dramatic melt over the course of three years.

In conclusion, and as the papers here attest, alpine areas throughout the circumpolar North are experiencing melting at alarming rates. This rapid melting is affecting extant caribou and reindeer herds, while revealing new archaeological finds. Archaeological research has been initiated in several jurisdictions to document these changes, though in many others, work has yet to begin. As a group, the papers in this volume suggest that the phenomenon of ice patch hunting could exist anywhere where humans and caribou or reindeer interacted at some point in the past in an alpine environment; the northern Rockies, Torngats, Baffin Mountains, the Pyrenees, the Altai, and the Urals, among others, all seem like mountain environments with high potential. With this in mind, perhaps the greatest contribution this collection of papers has to offer is inspiration.

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