

SPECIAL FORUM

Changes and Challenges in Glacial Archaeology

William T. T. Taylor

University of Colorado

William.Taylor@colorado.edu

As we move into the third decade of the twenty-first century, the discipline of glacial archaeology is responding to a rapidly changing world, and doing so in different ways in different areas of the globe. JGA reached out to leading scientists and scholars around the globe to get their perspective on two important questions:

What are the most important recent developments, innovations,
or contributions in the field of glacial archaeology?

What are the biggest challenges facing glacial archaeology in the next decade?

Our invited panelists include scholars working on four continents as well as the high arctic. The diversity of responses highlights some of the exciting changes taking place across the discipline, including an increasing integration of new technologies for remote sensing and mapping, exciting new efforts at using “citizen science” to identify important sites, a growing emphasis on interdisciplinary scientific collaboration with biomolecular researchers and environmental scientists. These advances have been complimented by a growing awareness of the importance of Indigenous collaboration, gender equity, and representation within the discipline. At the same time, these contributions highlight a wide range of serious challenges, especially the severity and speed of climate warming, the difficulty of funding and logistics, the vast scope of unsurveyed and under studied high latitude and mountain regions, the destructive impacts of looting and tourism, and political and professional impediments toward conducting glacial archaeological research.

Keywords: glacial archaeology, challenges, new directions

Glacial Archaeology: Progress and Future Directions

E. James Dixon

University of New Mexico

jdixon@unm.edu

Over the last few decades, we have seen the discipline of glacial archaeology shaped by both technological and cultural change. Glacial archaeology is inherently interdisciplinary and has experienced refinement of research methods emphasizing the increasing application of technology, including ice coring, remote sensing, satellite imagery, digitation of historic air photos/maps, drone surveys, 3-dimensional visualization, and ground (Ice) penetrating radar (GPR). It is reasonable to anticipate the future application of additional approaches such as seismic refraction, light detection and ranging (LIDAR), environmental DNA (eDNA), and an increasing array of sophisticated technological innovations and interdisciplinary research teams. Dating artifacts recovered from terrestrial sites is usually based on artifact associations with dated stratigraphic levels and depositional sequences. This method is seldom possible in glacial archaeology, and consequently artifacts melting from ice have sometimes been criticized as lacking stratigraphic or chronological context. However, preservation of organic artifacts is a signature characteristic of glacial archaeology, and organic artifacts are individually dated by accelerator mass spectrometry (AMS) and multiple dates are occasionally possible on composite artifacts made of different materials. The high precision ^{14}C AMS dating of individual artifacts results in chronological contexts that are often far superior to traditional chronologies defined by stratified sites and relative dating. This results in unique high-resolution chronologies facilitating advanced levels of analyses when applied to specific sites and artifact types.

The practice of glacial archaeology traditionally has been associated with the science of climate change. However, it has been challenging to use glacial and ice patch discoveries in larger interpretative contexts. Finds are often treated as one-of-a-kind curiosities, and it is often difficult to integrate discoveries into larger cultural and scientific frameworks and themes. Although cultural remains found melting from ancient ice are widely recognized as the result of global warming, “research” objectives are often limited to focused historic preservation efforts or “salvage” recovery. Cultural interpretations are often limited to obtaining unique snapshot views of rare organic artifacts or activities. While this approach is important, the database has become larger, increasingly diverse, and global. Consequently, it is suitable to address larger questions. For example, there are now enough radiocarbon and other dates that it may be possible to use them as “big data” to view and analyze dated artifacts and sites in relation to climate or technological change at regional or even

global levels. Some approaches might include analyzing these data by year of discovery, altitude, latitude, and/or other factors that might reveal previously unrecognized regional or ecosystem patterns of climate and cultural change.

Although it is widely recognized that the uptick in archaeological discoveries is linked to global warming, it is important to recognize that the character of contemporary climate change may be significantly different than it was in the past. This is because past global climate change was not anthropogenically induced, and the velocity and character of contemporary human response and adaptations may vary significantly from those of the past. Research challenges also exist in interpreting the role of glaciers and ice patches in subsistence (economic) systems. For example, ice patches and glaciers can be viewed from an energetic perspective in which select glaciers that served as mountain passes primarily conserved energy by providing people with easier (least cost pathways) over mountain ranges. In contrast, ice patches are primarily sites that concentrate harvestable energy in the form of animals that can be hunted at specific times of the year and consequently fit into a larger cultural energetic expenditure decision making matrix.

An important concern mentioned in detail in commentary by Ceruti is the need to increase awareness of governmental land managing agencies and personnel regarding the importance of incorporating glaciers and ice patches into their management and permitting thinking. Glacial archaeology is often logistically challenging and expensive, and there is a need for land managing agencies to provide additional funding to support this time-sensitive research. While some land managing agencies (particularly in Canada and some parts of Europe) have embraced and support glacial archaeology, ice patch research is sometimes obstructed by traditional concepts of historic preservation that advocate solely for *in situ* preservation of archaeological remains. However, this philosophical premise is inappropriate for glacial archaeology and it is important to encourage land managing agencies to facilitate access to, and provide research funding for, these sites.

Perhaps the most significant and rewarding trend in glacial archaeology is the growing recognition of the importance of the need to establish and maintain meaningful partnerships and collaborations with local and indigenous people whose traditional lands include perennial snow and ice. These relationships have been most strongly developed in regions where indigenous people have traditionally used, and are spiritually connected with, glaciers and ice patches. These partnerships have led to new and important insights into the relationships between people and ice, and underscore the relevance of glacial archaeology to society and science.

NORTH AMERICA

Glacial Archaeology in Yukon, Canada, 2018 to 2022

Christian Thomas¹ Sheila Greer² and Kelsey Pennanen³

1. Yukon Government
2. Champagne and Aishihik First Nations
3. University of Calgary

The past five years have been eventful for Yukon's Ice Patch Research Group, which includes the Yukon Government Archaeology Unit, and the Heritage Programs of the six Yukon Ice Patch First Nations—Carcross/Tagish First Nation, Champagne and

Aishihik First Nations, Kluane First Nation, Kwanlin Dün First Nation, Ta'an Kwäch'än Council, and Teslin Tlingit Council. We have reinvented how Indigenous and Territorial governments work together to organize field programs, curate, and interpret collections, as we continue to monitor our study area and recover spectacular pieces of ancient material culture.

Our co-operative approach is allowing for indigenous values and priorities to guide not only how our work gets done, but also what gets done. For example, one priority identified by our group was to better understand our mountains as indigenous hunting landscapes (Greer and Strand 2012; Hare *et al.* 2004). This led to the development of a project focused on alpine hunting blinds complexes (Figure 1). This research is being developed by Kelsey Pennanen of the University of Calgary's Department of

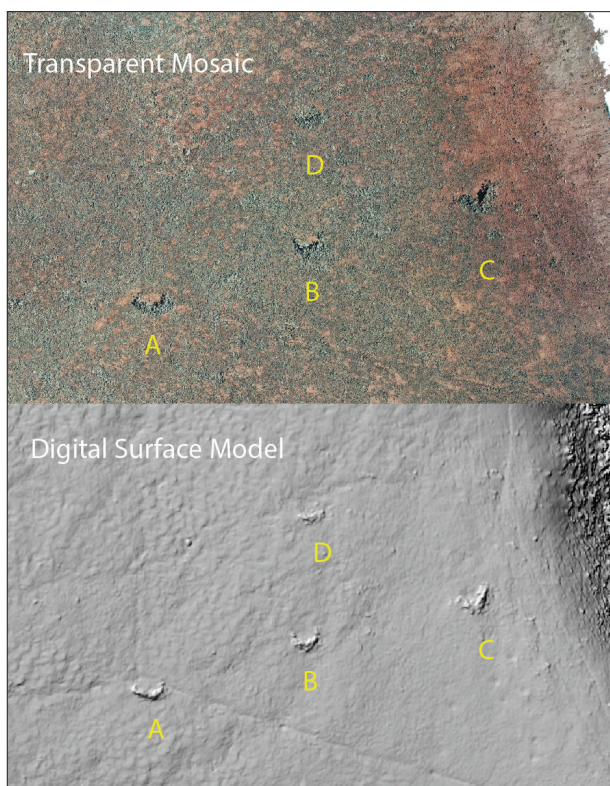


Figure 1. Showing true-colour orthomosaic (top) and digital surface model (bottom) of site JcUu-3 at Alligator Lake. Captured using a DJI Mavic 2 drone flown at a height of 40m above surface in a double grid flight pattern with 70% multi-directional overlap. Outputs were created using Pix4DMapper software.



Figure 2. View northwest at Friday Creek Ice Patch showing detail of the numerous animal trails leading from valley to mountain.

Anthropology and Archaeology, who is utilizing drone based aerial imagery to create detailed and interactive 3-dimensional visualizations of alpine hunting landscapes (Figure 1). These visualizations will be employed in future interpretive products and used as research aids when interviewing individuals that have experience hunting in these settings. The new focus on non-cryogenic landscape features has expanded our understanding of where hunters organized themselves in the mountains. During surveys to map game trails (Figure 2), drive lanes and hunting blinds in areas with two kilometers of ice patches 72 built stone structures have now been recognized 72 (up from 15 documented features in 2017).

The ice patch cultural data are playing a key role as well, in contemporary land planning work being undertaken by the Carcross/Tagish and Kwanlin Dün First Nations and Ta'an Kwäch'än Council (Carcross/Tagish First Nation *et al.* 2020). Data-sets of hunting blind complexes, other types of archaeological features and artifact distributions are being linked with current ecological models of caribou and sheep distribution, as derived from collaring data (Government of Yukon 2021). These data sets, along with Elders' and hunters' experiences on the land, will be combined to create a GIS-based interactive stacked-knowledge database that will demonstrate how the landscape has been used. Both a visually captivating public-facing digital heritage outreach platform, along with an interactive back-facing management portal requiring security clearances are being planned.

Extreme melt

The years 2018 and 2019 saw Yukon ice patches undergo extreme melt, which presented challenges for field monitoring activities. The limitations of weather, the length of the melt season, and our transportation budget determine where monitoring efforts are focused, and how much time can be spent at any place. About 330 ice patches have been recognized through satellite imagery in the Yukon study area.



Figure 3. Caribou hunting arrowhead made from antler and featuring a copper end-blade. This was the only artifact recovered from site JbUw-21 three weeks before the last of the site's ice completely melted away.

About half of these locales have been visited, with 43 being archaeological sites and a further 110 locales recognized as strictly paleontological sites containing only faunal specimens.

Our program has the means to monitor between 30 and 40 sites per year, and rarely do we get the opportunity to be onsite at any one ice patch for more than two or three hours. From the 2016 find of copper bladed arrowhead at Deuces Wild Creek (Thomas *et al.* 2020), we've learned that even the most ephemeral ice patch can produce a cultural heirloom of extreme value to the citizens of our First Nations (Figure 3). Happenstance also impacts fieldwork, as illustrated by a spectacular find in 2018.

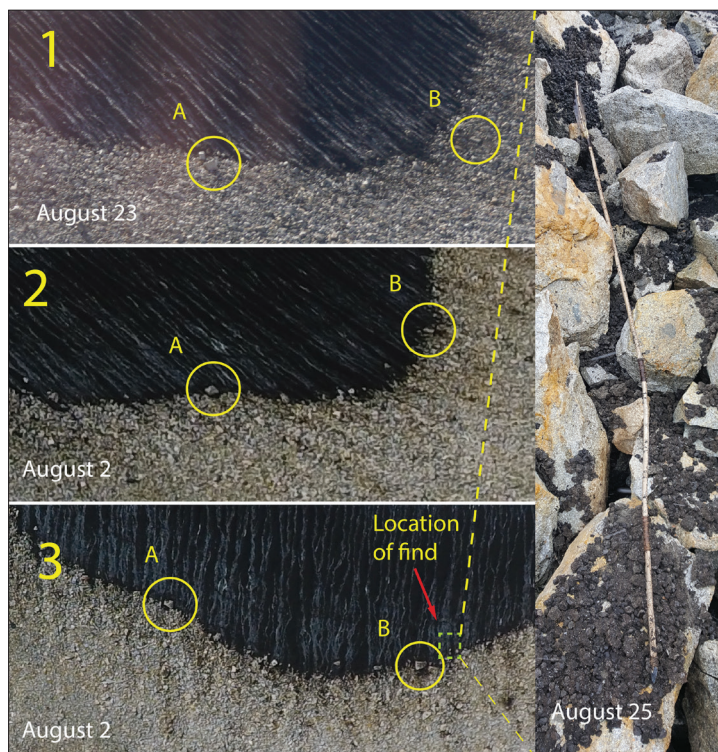


Figure 4. Comparative photos from JcUu-1 (Friday Creek Ice Patch) on different days in August 2018 illustrating the discovery location of 6,000 year old (UOC-8493) throwing dart.

In late July we completed ice patch survey as well as a preliminary assessment of hunting blind structures on the mountainous area where the Friday Creek and Alligator ice patches are located. With one last hour of flying time and decided to return to this site. This second visit resulted in the discovery of the world's only completely intact throwing dart that had melted out of the Alligator ice patch (Gatensby 2019) after a staggering 3 meters of ice had melted in the 3 weeks between the two inspections. Had we found this dart the following season



Figure 5. Hafted Hoodoo Mountain obsidian (Kluane Park) throwing dart point dated to 4861–5054 cal BP (UOC-18096) recovered from the traditional territories of the Carcross/Tagish First Nation. Artifact discovered 150 kilometers east of obsidian source.

it would likely have been recovered as an artifact in many pieces (Figure 4).

The melt conditions of 2018/2019 were optimal for artifact discovery and led to the collection of 46 whole or fragmented artifacts including an obsidian projectile point (Figure 5) and over 300 paleontological specimens. Still, we cannot ignore the negative ecological impact for the animals that use the ice

patches for summer thermal regulation and insect relief. In 2019, which was a dramatic melt year, ice entirely melted away at more than a dozen smaller patches. Further, the annual snow accumulation used by caribou and sheep for summer respite from parasitic insects (Ion and Kershaw 1989) had fully disappeared at all sites below 2200 m asl (Figure 6).



Figure 6. View southeast at Friday Creek in 2019 (right) and 2021 (left) showing extremes in snow accumulations. Both photos were captured in early August.

Extreme snowfall

During the period between 2020 through 2022 the region experienced three of the heaviest snow accumulations witnessed during the 25 year life of the Yukon ice patch research project (Figure 6, left). Despite high summer temperatures there has been little ice exposure at the patches. This slight reprieve from catastrophic melt and site loss has allowed greater emphasis on much needed collections care; and provided the opportunity to research how hunting has historically taken place on the mountains beyond the ice patches. We have also had the opportunity to better visualize what an ice patch landscape looks like with a full and persistent summer snowpack, and not surprisingly, the ice patches are being regularly used by animals. We have also been able to document where ephemeral snow accumulations may have formed and persisted during colder periods of the Holocene (Reckin 2013), suggesting further locales worthy of ground inspection.

The recent high volumes of snow persisting through the summer has not affected all sites equally. At our most ancient and largest ice patch, located in Champagne and

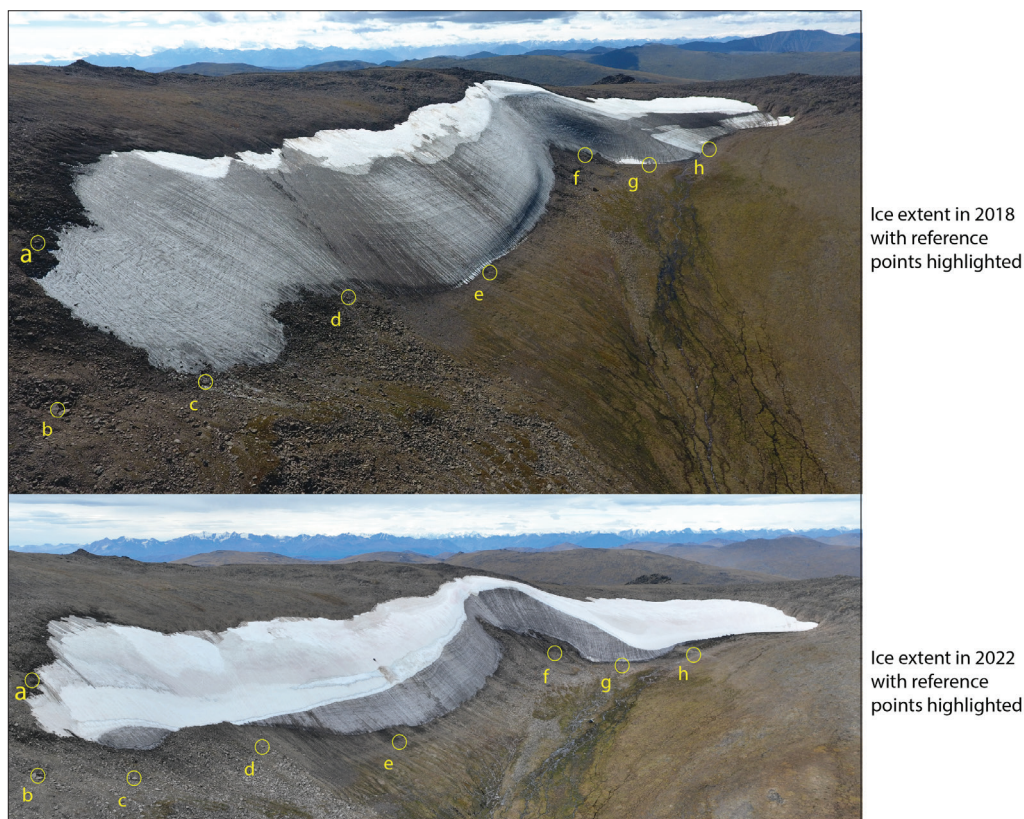


Figure 7. Comparative images of the Gladstone Ice Patch in the traditional territories of the Champagne and Aishihik First Nations. Circles highlight boulders that serve as visual reference points. View is approximately south by southwest in both images. East-west (long axis) ice extent is approximately 905 meters for the purpose of scale.

Aishihik First Nations territory, previous years melt had left the melting ice face so steep that snow is no longer accumulating in the volume required to prevent ice melt. Consequently, with increasing summer temperatures the 9,300-year-old Gladstone Ice Patch is wasting rapidly (Figure 7). This is the only ice patch that has produced artifacts since 2020, with 20 individual artifacts (refitted from 51 different fragments) recovered from this site alone.

Climate change is real and presents our team with dynamic challenges, but it is not the only story echoing out of the Yukon mountains. This landscape supports animal populations that have fed many people for hundreds of generations, and the descendants of the region's indigenous nations still come to these mountains to hunt. This also involves learning what it means to be member of and descendant from a hunting culture, and the responsibilities that fall from that belonging. By working together and focusing on both the tangible and intangible aspects of history and culture, we hope to help preserve that story by assisting the people of today in visualizing the land as their ancestors once saw it and implementing the lessons that can be drawn from that knowledge and understanding.

References

- Carcross/Tagish First Nation, Kwanlin Dün First Nation, and Ta'an Kwäch'än Council. 2020. "How we walk with the land and water." <https://www.howwewalk.org/>.
- Gatensby, A. 2019, April 1. "Intact, and older than the Egyptian pyramids." *Kwanlin Dün Ch'a*, 4–5.
- Government of Yukon. 2021, July 5. "Southern Lakes Caribou: Monitoring a recovering woodland caribou herd in Yukon." <https://storymaps.arcgis.com/collections/9849a0b2f05a47a2a190d49d74b56f9f>.
- Greer, S. and D. Strand. 2012. "Cultural landscapes, past and present, and the South Yukon ice patches." *Arctic* 65(5): 1–202. <https://doi.org/10.14430/arctic4189>
- Hare, P. G., S. Greer, R. Gotthardt, R. Farnell, V. Bowyer, C. Schweger and D. Strand 2004. "Ethnographic and archaeological investigations of alpine ice patches in southwest Yukon, Canada." *Arctic* 57(3): 233–324. <https://doi.org/10.14430/arctic503>
- Ion, P. G. and P. Kershaw. 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. <https://doi.org/10.2307/1551633>
- Reckin, R. 2013. "Ice patch archaeology in global perspective: Archaeological discoveries from alpine ice patches worldwide and their relationship with paleoclimates." *Journal of World Prehistory* 26: 323–385. <https://doi.org/10.1007/s10963-013-9068-3>
- Thomas, C. D., P.G. Hare, J. D. Reuther, J. S. Rogers, H. K. Cooper and E. J. Dixon. 2020. "Yukon First Nation use of copper for end-blades on hunting arrows." *Journal of Glacial Archaeology* 4: 1–23. <https://doi.org/10.1558/jga.40685>

Ice, Mountains, and People: Applying a Multi-proxy Approach to Reveal Changes in Alberta's Alpine Ecosystems through Ice Patch Research

**Diana Tirlea,¹ Todd Kristensen,² Aaron Osicki,³ Britta Jensen,⁴
Krista Williams,⁵ Richard Caners,¹ Lisa Lumley,⁵ and Robin Woywitka⁶**

1. Royal Alberta Museum 2. Archaeological Survey of Alberta
3. Parks Canada 4. University of Alberta 5. University of Alberta/Alberta
Biodiversity Monitoring Institute 6. MacEwan University

Glacial archaeology has grown and progressed rapidly in recent decades with technological innovations and shifting socio-political issues. However, research on ice patches in the Canadian Rocky Mountains is in its infancy. While Holocene glacial ice retreat, advance, and morphology are well studied in Canada, ice patches in general tend to be understudied because of their limited geomorphological impact on landscapes. This oversight is concerning as their isolated nature, lower elevation, and small mass make ice patches even more susceptible to climate change than glaciers. The importance of documenting these features is heightened by a persisting but tenuous biological importance to a range of modern species. The lack of flow in ice patches also makes them excellent archives of palaeoenvironmental and organic-based cultural materials, as layers of ice and preserved contents are not as distorted as they may be by flow in glaciers.

Because of their isolation and fragility, ice patches are a challenge to access and regularly monitor through remote sensing, historical satellite imagery, and fieldwork. New innovations like detailed digital elevation models, high resolution and recurring satellite photographs, drone mapping, and ground penetrating radar present exciting avenues to document changes remotely and/or maximize field time and data recovery to quantify ice patch volume and short-term variability. These innovations coupled with established approaches have started to yield new insights into Rocky Mountain ice patches.

Unlike ice patch programs in northern Canada (e.g., Hare *et al.* 2012 and Vanderhoek *et al.* 2012), ice patches in Alberta, to date, have yielded few ancient objects. Although this may change with increased study, the focus of our research has shifted to understanding their ecological importance and palaeoenvironmental change through time. Our work has demonstrated that ice patches in the Rocky Mountains were, and are still, used by caribou and bison; a key insight as institutes like Parks Canada and the Government of Alberta grapple to manage caribou populations teetering on local extirpation (Environment Canada 2014) and to reintroduce once native species like bison (Steenweg *et al.* 2016). The challenge and opportunity here is to situate ice patch archaeology into a broader ecological management framework in the face of climate change (see Bowyer 2014 and Galloway *et al.* 2012 for studies of caribou ecology at North American ice patches).

Further, project members are discovering new methods to distinguish the stratigraphy and formation of ice patches from other palaeoenvironmental studies (such as lake core analyses) with corollary requisites for multiple radiocarbon dates, multiple ice extraction methods (block and cylindrical core), field extraction protocol, and the use of LiDAR to document associated ice-based landforms. More work is required to reliably date and interpret ice patch samples, including the extraction of

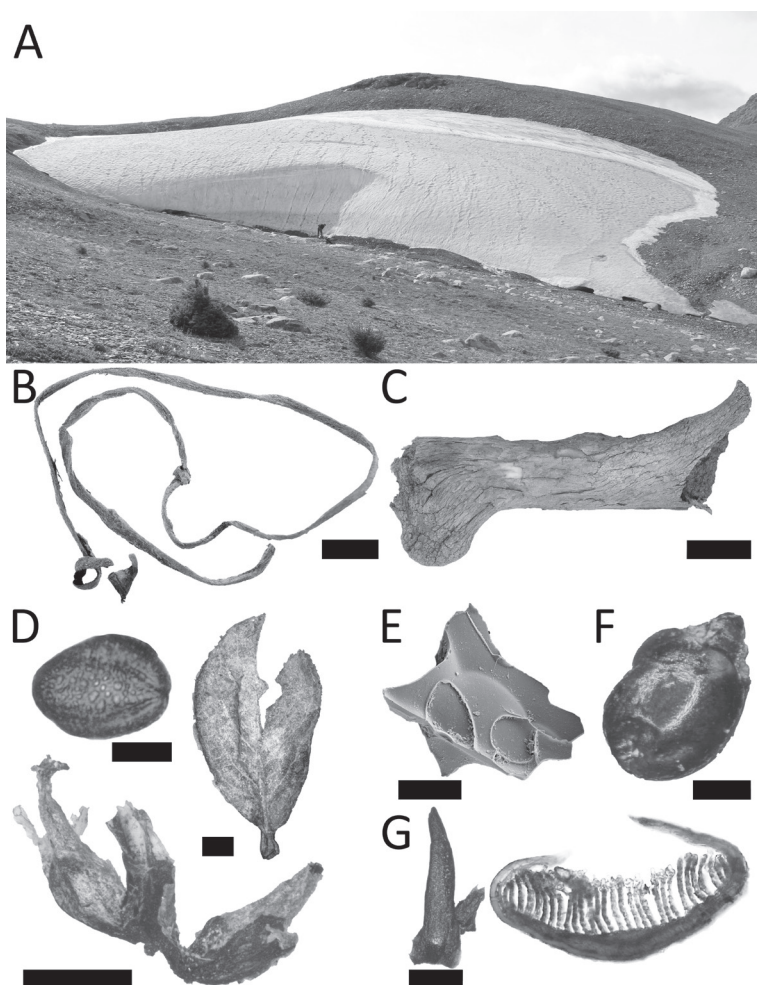


Figure 1. (A) Ice patch CM-II-IP 2709R, one of 23 ice patches surveyed in the Canadian Rockies for cultural and faunal material. This includes (B) a knotted leather strap, 270 ± 20 ^{14}C yr BP (UGAMS 22077; scale=2 cm) and (C) a bison bone, 4074 ± 27 ^{14}C yr BP (UOC-12558; scale=5 cm). A total of two ice patches, including CM-II-IP 2709R, in Jasper National Park have been sampled for palaeoenvironmental material, which includes (D) *Salix cf arctica* pollen (scale=10 μm), leaves (scale=2 mm), and flowers (scale=1 mm); (E) Mazama Ash (scale=50 μm); (F) oribatid mites (scale=0.2 mm); and (G) *Polytrichum juniperinum* moss leaves (scale=1 mm, with c.s. of leaf) (images: R. Caners, moss; B. Jensen, ash; T. Kristensen, strap, bone; D. Tirlea, ice patch, macros, pollen).

multiple cores from each patch, and to compare those results with other ice patches. To that end, we are targeting climate proxies preserved in the ice patches, such as stable isotopes and pollen, to infer changes in temperature, precipitation, and treeline during the Holocene. Relatively abundant organic materials within the layers of ice are datable by radiocarbon and provide chronological control to patch development and Holocene landscape fluctuations (e.g., Chellman *et al.* 2021). These results can be used as independent dates to support recovered objects. In addition, volcanic ash (or tephra) can provide independent age control if they have been previously identified and dated (e.g., Bridge River, Mount St. Helens Yn and Mazama; Jensen *et al.* 2019).

An additional challenge is to effectively utilize the ice cores and blocks that we extracted, and to archive these materials for future generations as they disappear from the landscape. Perhaps more so than other subfields of archaeology, ice patch work is increasingly collaborative. Collaboration here includes the involvement of ice core facilities (the Canadian Ice Core Lab), specialists to study samples (Royal Alberta Museum, Alberta Biodiversity Monitoring Institute), heritage managers to coordinate efforts (Parks Canada, Archaeological Survey of Alberta), and university researchers to drive the program (MacEwan University, University of Alberta). This network of collaborators has enabled detection of other valuable data sources like oribatid mites (that reveal specific microhabitats and biological diversity), tephra (which serve as chronological markers and potential stimuli of broad or local climatological change), and bryophytes (to provide basal ice dates and context for analysis of vegetation chronologies). Oribatid mite subfossils have been used to discern past environments (e.g. Larsen *et al.* 2006; Markkula and Kuhry 2020) and we are using them to reconstruct past environmental change in alpine systems. Bryophyte material entombed in ice can remain viable long-term (La Farge *et al.* 2013; Miller 2017) with important implications for ice patch research (Patiño *et al.* 2022), potentially influencing plant refugia concepts and recolonization of plant communities after ice loss. Further, well preserved and abundant plant macrofossils from ice patches, allows for high taxonomic precision and species-level datasets ideal for palaeoecological reconstructions of local vegetation communities (Birks and Birks 2000).

On a logistic level, major challenges include securing funding from humanities-based agencies and establishing meaningful relationships with Indigenous communities when so little tangible archaeological material has been found. Across North America, Indigenous knowledge is needed to help identify and interpret cultural adaptations associated with changing environments (e.g., Andrews *et al.* 2012; Greer and Strand 2012; Greer *et al.* 2021). We strive to move beyond the fascination of patches as icy treasure chests of unique human materials to a conception of them as ecocultural resources, through their capacity to reveal long-term patterns of human impact in alpine landscapes. Of major relevance of this historical science is to envision the trajectory of ice patch and glacier changes into the future to understand the ecological opportunities that vanish and emerge. Palaeoecological research on ice patches will guide the management of mountain spaces and how we envision our place within them.

References

- Andrews, T.D., G. MacKay, L. Andrew, W. Stephenson, A. Barker, C. Alix and 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(5): 22–42. <https://doi.org/10.14430/arctic4183>
- Birks, H.H. and H.J.B. Birks. 2000. "Future uses of pollen analysis must include plant macrofossils." *Journal of Biogeography* 27: 31–35. <https://doi.org/10.1046/j.1365-2699.2000.00375.x>
- Bowyer, V.E. 2014. "Pollen analysis of caribou dung from ice patches in southwest Yukon: Ancient caribou ecology and implications for precontact human land-use." *Journal of Glacial Archaeology* 1: 117–139. <https://doi.org/10.1558/jga.v1i1.117>
- Chellman, N.J., G.T. Pederson, C.M. Lee, D.B. McWethy, K. Puseman, J.R. Stone, S.R. Brown and J.R. McConnell. 2021. "High elevation ice patch documents Holocene climate variability in the northern Rocky Mountains." *Quaternary Science Advances* 3: 1–8. <https://doi.org/10.1016/j.qsa.2020.100021>
- Environment Canada. 2014. *Recovery strategy for the woodland caribou, southern mountain population (Rangifer tarandus caribou) in Canada*. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa.
- Galloway, J.M., J. Adamczewski, D.M. Schock, T.D. Andrews, G. MacKay, V.E. Bowyer, T. Meulendyk, B.J. Moorman and S.J. Kutz. 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(5): 59–79. <https://doi.org/10.14430/arctic4185>
- Greer, S. and D. Strand. 2012. "Cultural landscapes, past and present, and the south Yukon ice patches." *Arctic* 65(5): 136–152. <https://doi.org/10.14430/arctic4189>
- Greer, S., C.D. Thomas, K. Chambers, D. Tirlea, A. Osicki, T. Kristensen and C.M. Lee. 2021. "Von der Speerschleuder bis zur Musketenkugel: Gefrorene Geschichten Nordamerikas." In *Gletscherarchäologie: Kulturerbe in Zeiten des Klimawandels*, edited by T. Reitmaier. Archäologie in Deutschland, special issue 21(2), 70–80. Darmstadt: wbg Theiss.
- Hare, P. G., C.D. Thomas, T.N. Topper and R.M. Gotthardt. 2012. "The archaeology of Yukon ice patches: New artifacts, observations, and insights." *Arctic* 65 (5): 118–135. <https://doi.org/10.14430/arctic4188>
- Jensen, B.J., A.B. Beaudoin, M.A. Clynnne, J. Harvey and J.W. Vallance. 2019. "A re-examination of the three most prominent Holocene tephra deposits in western Canada: Bridge River, Mount St. Helens Yn and Mazama." *Quaternary International* 500: 83–95. <https://doi.org/10.1016/j.quaint.2019.03.017>
- La Farge, C., K.H. Williams and J.H. England. 2013. "Regeneration of Little Ice Age bryophytes emerging from a polar glacier with implications for totipotency in extreme environments." *Proceedings of the National Academy of Science* 110(24): 9839–9844. <https://doi.org/10.1073/pnas.1304199110>
- Larsen, J., A.E. Bjune and A. de la Riva Caballero. 2006. "Holocene environmental and climate history of Trettetjørn, a low-alpine lake in western Norway, based on subfossil pollen, diatoms, oribatid mites, and plant macrofossils." *Arctic, Antarctic, and Alpine Research* 38(4): 571–583. [https://doi.org/10.1657/1523-0430\(2006\)38\[571:HEACHO\]2.0.CO;2](https://doi.org/10.1657/1523-0430(2006)38[571:HEACHO]2.0.CO;2)
- Markkula, I. and P. Kuhry. 2020. "Subfossil oribatid mite communities indicate Holocene permafrost dynamics in Canadian mires." *BOREAS* 49(4): 730–738. <https://doi.org/10.1111/bor.12444>
- Miller, B. 2017. "Yukon Ice Patches: Role of Ice-Entombed Bryophytes in Alpine Environments." MSc. Thesis. University of Alberta. <https://doi.org/10.7939/R38G8FX4M>
- Patiño, J., I. Bisang, B. Goffinet, L. Hedenäs, S. McDaniel, S. Pressel, M. Stech, C. Ah-Peng, A. Bergamini, R.T. Caners, D.C. Cargill, N. Cronberg, J. Duckett, S. Eppley, N. J. Fenton, K. Fisher, J. González-Mancebo, M. Hasebe, J. Heinrichs, K. Hylander, M.S. Ignatov, J. Martínez-Abaigar, N.G. Medina, R. Medina, D. Quandt, S. A Rensing, K. Renzaglia, M. Renner, R. M. Ros, A. Schäfer-Verwimp, J. C. Villarreal and A. Vanderpoorten. 2022. "Unveiling the nature of a miniature world: A horizon scan of fundamental questions in bryology." *Journal of Bryology* 44(1): 1–34. <https://doi.org/10.1080/03736687.2022.2054615>
- Steenweg, R., M. Hebblewhite, D. Gummer, B. Low and B. Hunt. 2016. "Assessing potential habitat and carrying capacity for reintroduction of plains bison (*Bison bison bison*) in Banff National Park." *PLoS ONE* 11(2): 1–22. <https://doi.org/10.1371/journal.pone.0150065>
- Vanderhoek, R., E. J. Dixon, N. L. Jarman and R. M. Tedor. 2012. "Ice patch archaeology in Alaska: 2000–10." *Arctic* 65(5): 153–164. <https://www.jstor.org/stable/41638615>

Overview of Interdisciplinary Ice Patch Research in the Greater Yellowstone Region, USA

Craig M. Lee

Montana State University

Ice patch research in the Greater Yellowstone Ecosystem (GYE) is increasingly interdisciplinary. Efforts to obtain paleoclimatic proxies obtained from ice patches and peri-ice patch environments are being coupled with archaeoecological observations to posit linkages between climate and the activities of Indigenous populations during the Holocene. The 2016 Camp Monaco Prize (McClure 2016) and a subsequent award from the US National Science Foundation (NSF 2018) accelerated this transition. Both projects focused on obtaining ice cores from ice patches in areas where organic artifacts were exposed by melting ice. This contribution highlights much of the ongoing work, but it is far from exhaustive.

Efforts through 2022 have resulted in ice cores from ice patches in three distinct clusters. The research/project teams have been thwarted by “dirty” ice conditions, which requires drilling through layers of organic material and inorganic grit as well as ice. These challenges are being met through the development and production of new coring devices under the direction of David Christiansen (University of Wyoming).

Chellman *et al.* (2021) used ice accumulated over the past 10,000 years to document generally cooler and wetter conditions during the early Holocene followed by a period of anomalous winter season warmth preceding a return to cooler and wetter winters. Following the attempts of Ackerman *et al.* (2021), Nathan Chellman, Joe McConnell (Desert Research Institute), and others are employing ground-penetrating radar (GPR) to measure the depth of seasonal snow on top of ice patches, as well as to observe bottom profiles and internal structure that may eventually be correlated with direct observations made via ice cores. Kathryn Puseman (Paleosciences Archaeobotanical Services Team) has been analyzing macrobotanical remains that coalesced on ancient melt horizons, while other, including Mio Alt (Montana State University), have been studying associated pollen records.

Danny Stahle (2022) recently completed an extensive study of over 30, large diameter (>20 inches diameter at breast height), intact whitebark pine (*Pinus albicaulis*) trees emerging from an ice patch. Through classic dendrochronological cross-dating methods, Stahle and colleagues discovered that all the sampled trees grew contemporaneously over a 600-year period between 5200–5800 years ago. In addition to directing the dendrochronological study and collecting ice cores, Gregory Pederson (US Geological Survey) is obtaining multiyear borehole measurements on ice patches using thermistor strings and data loggers. David McWethy (Montana State University) and colleagues have collected sediment cores from meltwater ponds

associated with ice patches and a unique palsa fen. Elizabeth Flesch and colleagues have continued their efforts comparing ancient and contemporary bighorn sheep populations using bones recovered from archaeologically productive ice patches.

As of 2022, there are many collaborators participating in this research, including Indigenous community members Shane Doyle, D. Lynette St. Clair, Aaron Brien, and others. Progress reports on some of these efforts were shared at the recent Frozen Pasts 5 conference, which was held in Montana in September 2021 (Lee and Dixon, this volume).

We are continuing to refine techniques to identify ice patches where archaeological material might be encountered using aerial overflights. We also continue to survey new areas and resurvey known locations through the support of the National Park Service and colleagues (Elizabeth Horton, Yellowstone National Park) and the US Forest Service and colleagues (Kyle Wright, Shoshone National Forest, Halcyon LaPoint and Mike Bergstrom, Custer Gallatin National Forest). The most recent synthesis meeting, organized by David McWethy, occurred in Red Lodge, Montana from September 10 to 13, 2022.

References

- Ackermann, B., C. Lee, D. McWethy, N. Chellman and J. McConnell. 2021. "An Application of Ground-Penetrating Radar at a Greater Yellowstone Area Ice Patch." *Journal of Glacial Archaeology* 5: 73–83. <http://doi.org/10.1558/jga.19883>
- Chellman, N., G. Pederson, C. Lee, D. McWethy, K. Puseman, J. Stone, S. Brown and J. McConnell. 2021. "High elevation ice patch documents Holocene climate variability in the northern Rocky Mountains." *Science Advances* 3(100021). <https://doi.org/10.1016/j.qsa.2020.100021>
- Lee, C. and E. Dixon. 2022. "Frozen Pasts 5: Glacial and Ice Patch Archaeology during the COVID-19 Pandemic." *Journal of Glacial Archaeology* 6(1).
- McClure, N. 2016 "Center of the West and partners announce latest Camp Monaco Prize winners." <https://centerofthewest.org/2016/04/28/2016-camp-monaco-prize-winners/>
- National Science Foundation (NSF). 2018. "Reconstructing Ancient Human and Ecosystem Responses to Holocene Climate Conditions." https://www.nsf.gov/awardsearch/showAward?AWD_ID=1832486
- Stahle, D. 2022. "A Forest Entombed in Ice: A Unique Record of Mid-Holocene Climate and Ecosystem Change in the Northern Rocky Mountains, U.S.A." Unpublished MSc thesis, Montana State University.

SOUTH AMERICA

Through Thick and Thin Ice

Constanza Ceruti

Catholic University of Salta (UCASAL), National Council for Scientific Research in Argentina (CONICET), National Academy of Sciences in Buenos Aires (ANCBA)

In addition to the difficulties of ice-covered mountain terrains, there are many complications that glacial and high-altitude archaeologists often face while performing their duties as both, scientists, and climbers. Based on my professional experience spanning over four decades, the biggest obstacles to mountain archaeology in the near future are excessive bureaucracy, lack of recognition of merit, political correctness and professional jealousy, affecting science in general, and our field in particular.

A widely spread problem, especially at southern latitudes, is that permits for field research and access to collections are often granted or arbitrarily restricted by bureaucrats with no academic background. It may be the case that someone without any experience in science (a painter or poet, for example) becomes a Secretary of Culture or Heritage Director, thanks to family connections or ideological affinities with local politicians. Nepotism and lack of professional experience, in the hands of powerful bureaucrats, can become a recipe for disaster, particularly in areas where serious archaeological research is threatened by non-scientific interests, such as those of mining companies.

Another serious problem is caused by an overemphasis on political correctness, and adherence by scholars and the general public to politically motivated agendas that have little to do with the search for evidence-based knowledge. In recent years research projects have been delayed or stopped unnecessarily across many corners of our world.

Gatekeeping also remains an issue within academia. When attempting to publish the results of our work, glacial archaeology articles may suffer from difficulties in the process of finding appropriately-qualified reviewers. Calls for anonymity (and other excessively bureaucratic aspects in the peer review process) tend to exacerbate the issues of an already dehumanizing “publish or perish” system, in which pettiness and jealousy are oftentimes allowed to persist over merit.

The history of an emerging line of research should not remain ignored by the younger generations of scholars coming into the field of glacial archaeology. An honest recognition of the contributions of the pioneers is essential, particularly at times when the foundations of a scientific discipline are being established. In the case of glacial archaeology, it is not only “the founding-fathers” from the northern hemisphere that should be taken into consideration. It is important to recognize the



Figure 1. The author climbing above 6000 meters (20,000 feet) during archaeological field-work in the Andes of Argentina.

contribution of founding female scientists, particularly those from Latin America. My own archaeological research in the high Andes (as the only woman specialist in the world at the time), covers more than one hundred ascents on mountains above 5000 meters, in addition to co-directing (with Johan Reinhard in 1999) the expedition to the summit of volcano Lullllaillaco, the highest archaeological site on earth, where we discovered three perfectly preserved frozen Inca mummies and numerous offerings (Ceruti 2014). In the mid nineties, I had to overcome challenges presented by extreme weather and remote locations without access to proper technical equipment, without the assistance of helicopters or the chance of emergency calls. I also had to confront the skepticism of armchair archaeologists about any project involving a woman working on high mountains. However, my twenty-five years of intense teaching and international lecturing, the dozens of papers and books published, the numerous awards received and the worldwide media coverage of my work and its results, have all contributed to initial awareness on the importance of the archaeological heritage in high mountains.

I am thankful that we have come to a point in which honest reflections on our scientific praxis are being welcomed. In previous years, in view of some of the problems mentioned above, I have tried to advocate for the formation of an Association of Glacial Archaeologists (although a motion introduced towards this end at the Frozen Past meeting was met with cold indifference). Nowadays, I would recommend being outspoken, in defense of our individual and collective legacies. We, glacial archaeologists, are mountain and high-latitude people (sometimes by birth and always by choice). Our inspiration should be found amidst the wisdom of the Scottish highland-

ers, the “free men” of the Alps, and other mountain cultures and communities across the world and through human history, which have kept the fire burning. We can and we should, follow in their footsteps.

References

- Ceruti, M.C. 2014. “Overview of the Inca Frozen Mummies from Mount Llullaillaco (Argentina).” *Journal of Glacial Archaeology* 1: 79–97. <https://doi.org/10.1558/jga.v1i1.79>
- Ceruti, M.C. 2016. “Inca mountaintop shrines and glaciers in the high Andes.” *Journal of Glacial Archaeology* 3: 95–111.

EURASIA

Glacial Archaeology Is Coming of Age

Lars Pilø

Innlandet County Council, Norway

Even though there are known archaeological finds from the glacial ice discovered all the way back to 1914, it would be fair to say that glacial archaeology only really started to develop as a discipline in its own right after the mass melt out of finds in the Yukon from 1997 onwards. Since then, glacial archaeological sites and finds have appeared in a number of places around the world, as a consequence of the melting mountain ice caused by anthropogenic climate change.

I think back to 2007 when I started in the glacial archaeology business in Innlandet County, Norway, one year after the melt-out of hundreds of finds here in 2006. At the time, we were a bit shell-shocked: How many sites and finds were there and where was the funding to salvage the artefacts? The realization gradually dawned on us that this was not a temporary challenge. Instead, this challenge was closely linked to climate change and the melt was going to continue until all the ice was gone.

Fast forward 15 years and the support for research has improved in Innlandet, and there is now a permanently funded program for glacial archaeology in cooperation with the Museum of Cultural History in Oslo. Every year, we head up to the high mountains to survey for new sites and follow up on our known sites. We have conducted large systematic surveys on nine large sites (those producing more than 100 finds each) covering hundreds of thousands of square meters, and on many smaller sites as well. Sixty-five sites are now known and more than 3700 finds have been collected in our study region. We have created the *Secrets of the Ice* website and social media to inform the public and media about glacial archaeology, produced a local exhibition of our finds, and managed to publish eight peer reviewed scientific papers.

On a global scale, glacial archaeologists now know a lot more about the site formation processes on ice patch sites than 20 years ago. Our sites play by very different rules than the sites in the lowlands. We have learned more about the history and nature of the ice on a number of sites, and how formation processes and taphonomy influence the survival of artefacts. We have a better understanding of how different types of materials survive over time and how that differential preservation influences the artefact record. Our fieldwork methods are becoming more settled and traditional archaeological field methods have been adapted to glacial environments. A large number of site and artefact studies have been published, including studies that link sites to the larger landscape.

Glacial archaeology is now taking place in North America, the Alps, Scandinavia, and Mongolia. The sites in Mongolia were found recently through targeted efforts.



Figure 1. Nock and fletching on an arrow dated to AD 300-600, found during systematic survey on an ice patch site in the Jotunheimen Mountains, Norway in 2019. The front end was still frozen in the ice. Photo: Espen Finstad/Glacier archaeology Program Innlandet.

They highlight that finds melting out of glacial ice in remote mountain ranges are likely to be lost without such targeted surveys. The most glaring example of unstudied and important glaciated mountain ranges is the Himalayas. In many areas, important trade routes have crossed this large mountain chain for centuries or millennia, and some of the routes crossed glacial ice. Today, these routes are no longer used, as highways have been built. What happens to the archaeology here as the ice melts?

However, even in less remote areas, it has proved difficult to establish permanently funded programs, such as those existing in Yukon and Innlandet. Instead, glacial archaeological fieldwork is mostly conducted as part of the

regular archaeological heritage management, with more emphasis in years of heavy melting. However, without long term targeted efforts to survey for new sites, there is always the risk that new sites may not be discovered and finds will be lost.

This is the state of affairs from an archaeological perspective and additional information can be collected from the ice, not the least of which is climate evidence. Current climate prognoses tell us that most of the high mountain ice will melt completely in this century. Without a systematic collection of ice cores, valuable climate information will be lost. This fact is significant because the link between glacial archaeology and paleoclimate is complex and has not been adequately explored. There are currently only limited European efforts in this field, most notably in the Alps.

The last topic I would like to touch upon is the misuse of glacial archaeology for climate science denial. I think that most of us have experienced such misuse in comment sections to our media stories. This situation can be frustrating. On the *Secrets of the Ice* social media, we get our fair share of comments from climate science deniers, especially on Facebook when our posts go viral. We take our editorial commitments seriously, and do not allow spreading of climate misinformation on our pages. We try to use such comments as educational opportunities, but hard denial gets deleted. These discussions are also a sign that glacial archaeology has a role in the discourse on climate change, and shows the importance of public outreach in our discipline.

In summary, we have come a long way from the first mass melt-out of finds in Yukon to where we are today. Glacial archaeology is coming of age. Finds are pre-

served for the future through a massive effort by the glacial archaeological community and finds and stories are regularly covered by large international media outlets. The public is becoming increasingly aware of our field and our discoveries, including the link to anthropogenic climate change. Top climate scientists are following and sharing our work on social media. Our shared efforts are a great example of why archaeology matters.

However, there is certainly no reason to become complacent. Many sites remain undiscovered and many invaluable artefacts are being lost. We need to strengthen our efforts, and the melt is not stopping. If anything, it is accelerating, and we have a lot of work ahead of us before the ice is gone, and glacial archaeology will transform from an exciting field discipline to a study of what we were able to recover.

Ice Covered Heritage: Recovering Memories in Glacial Contexts in the Italian Alps

Franco Nicolis

Archaeological Heritage Office, Autonomous Province of Trento, Italy

In the editorial of the first issue of *JoGA*, the fundamental characteristics of our sub-discipline were clearly outlined, with glacial archaeology defined as “inherently interdisciplinary, international, and integral to the science of climate change” (Dixon *et al.* 2014, 3). High-altitude and high-latitude glacial environments are globally distributed; they are characterized by an exceptional preservation of organic material culture and therefore they are special archaeological, biological, and palaeontological archives to explore and reconstruct human adaptation to extreme environments. Glacial archaeology has few chronological boundaries, and very often the finds it produces overlap deeply with the cultural memory of local communities and indigenous people.

Glacial archaeology therefore has the privilege of providing researchers with a spectrum of material culture so well preserved that it allows a far more detailed reconstruction of the past than other branches of our discipline. For example, perhaps no human remains have ever been analysed and studied to the extent seen by Ötzi, the Iceman, one of the first and more significant icons of Glacial Archaeology. Additional analysis and study of the Neolithic bow case made of birch bark, rawhide and other materials found on the Schnidejoch in Switzerland gave us information that we could not have otherwise learned

However, the good preservation of some glacial archaeology finds is paired with their extreme fragility and what are often great research opportunities sometimes become critical conservation issues. Indeed, the cryosphere is melting, global warming is becoming increasingly pronounced, and glacial archaeological contexts are changing dramatically.

For several years the absence of regular snowfall in the Italian Alps has prevented glacial basins from compensating for the effects of summer melting. The withdrawal of alpine glaciers is characterized by a significant reduction in the thickness of the glaciers also at higher altitudes. The consequences of these natural events include the increasingly frequent emergence of artifacts left by people in the mountains, which were previously sealed for decades, centuries, or even millennia by layers of ice and snow.

The sudden change in melt conditions has led to a crisis for the recovery and conservation of finds, as a result of the extreme vulnerability of the materials to changing environmental conditions. Moreover, the geographical location of glacial sites is typically at high altitudes, where rapid changes in weather often causes major logistical problems and pose strict limits on the time windows for conducting field research. Sites are sometimes plundered by collectors who remove artifacts and disturb their archaeological context. An increasing number of finds, which must be conserved and scientifically analysed, presents another direct concern for archaeologists, who find themselves undertaking difficult recovery procedures to acquire as much information as possible regarding cultural and historical contexts.

Glacial archaeological finds also present grim, yet important, insights even into the more recent past. In the alpine Trentino region (Northern Italy), which was part of the Austrian-Hungarian empire until 1918, the so-called “White War” took place. This unique battlefield of WWI was fought at very high altitudes, often above 3,000 metres—even in glacial environments. Nowadays, glacial melt is revealing the traces of the White War, including large amounts of material abandoned by the armies (including the remains of soldiers).

The discovery of the bodies of soldiers of the First World War presents special ethical challenges, which require striking the right balance between scientific methodology, ethics, and forensic science. The ethical treatment of human remains is a common challenge for archaeologists working on very different glacial contexts all over the world (e.g. Alps, Andes, Antarctica, Himalaya, and the Americas). As in many other Indigenous communities around the world, the fallen soldiers of the Italian Alps have known identities and intimate ties to living communities. Recovering their remains from the melting ice demands respect for, and engagement with, local communities, their ancestors, and those whose material and spiritual lives were linked to these high mountain environments.

Rapid climate change challenges glacial archaeology to also adapt its approaches to the study of glacial environments just as quickly. The strong effects of global warming on alpine glaciers pushes us to develop new techniques for protecting and monitoring sensitive sites and to minimize the loss of glacial archaeological sites and their contexts. Doing so requires adopting new and adapting old technologies for the observation, conservation, and analysis of changing environmental contexts. This involves employing emerging techniques such as remote sensing, satellite imagery, and geostatic tools, in conjunction with better informed use of classic maps and cartography.

References

- Dixon, E.J., M. Callanan, A. Hafner and P. G. Hare. 2014. “The Emergence of Glacial Archaeology.” *Journal of Glacial Archaeology* 1: 1–9.

A Glacial Archaeology Update from the Canton of Valais, Switzerland (and a call for citizen scientists)

Ralph Lugon,¹ Philippe Curdy² and Stephanie R. Rogers^{3*}

1. University of Applied Sciences HES-SO Valais-Wallis

2. Valais History Museum (retired)

3. Department of Geosciences, Auburn University (*corresponding author)

It has been a decade since a major glacial archaeological project was funded by the Swiss National Science Foundation to locate archaeological material at high altitudes in the Pennine Alps (SNSF 2022), on the southern border of the Canton of Valais in Switzerland. Over the course of that project, which concluded in 2014, historians, archaeologists, and geographers worked together to locate areas of high glacial archaeological potential to preserve cultural heritage (Rogers *et al.* 2018; Eschmann Richon 2014). Models were created using Geographic Information Systems (GIS) and several locations were prospected to test the efficacy of the model results (Rogers and Curdy 2015; Rogers, Fischer, and Huss 2014; Rogers, Collet, and Lugon 2014). Additional modeling was conducted for the Bernese Alps (northern border of Valais) after the conclusion of the initial Pennine Alps project (Figure 1). There are still many sites, with designations of both high and low glacial archaeological potential, which have not, and may not ever be, prospected due to the vast and rugged terrain in which they occur. However, work is still on-going, and this update will comment on three glacial archaeological advancements that have occurred in the Canton of Valais over the last several years.

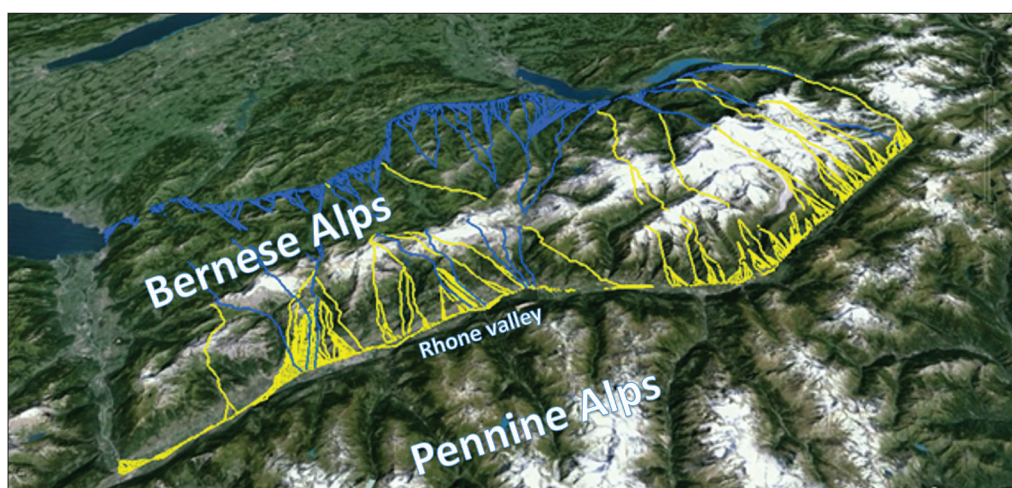


Figure 1. Least cost path model of potential paths traversed through the Bernese Alps; in yellow, from south to north; in blue, from north to south.

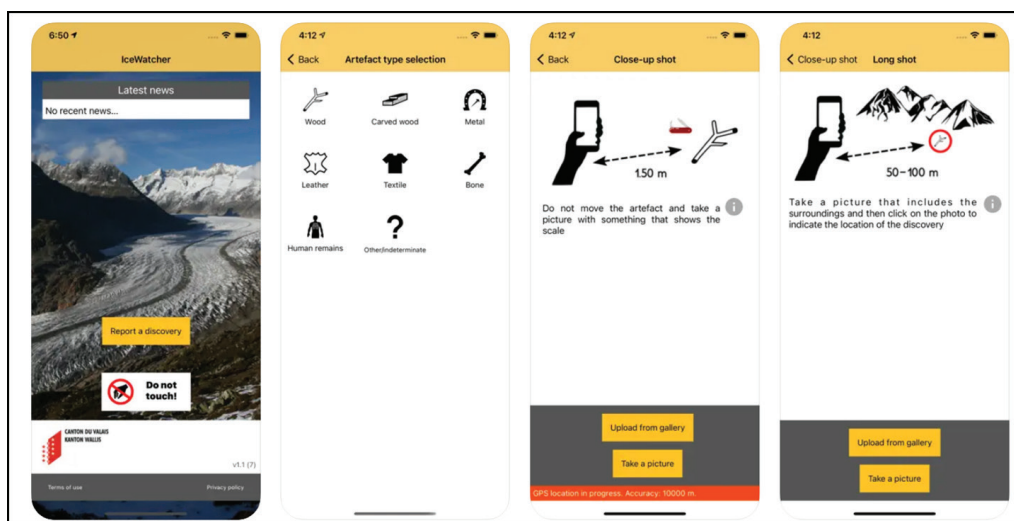


Figure 2. Overview of the IceWatcher application from the iOS platform (IceWatcher 2022).

Recent archaeological finds from modeled locations: Col Collon

The Col Collon is currently deglaciaded and located in the Pennine Alps between Switzerland and Italy. Due to the location of the pass, and the timing of deglaciation, it was considered a pass of “high glacial archaeological potential” in a GIS model (Rogers, Fischer, and Huss 2014). Thus, archaeologists visited the site to investigate the model results in 2018. Prospection led to the collection of several fragments of wood with no obvious traces of shaping or alteration. However, any wood found at high altitudes (above the treeline) is assumed to have been transported there by humans. The wooden fragments were dated to two periods during the Iron Age, 8th–5th century BC, and several were determined to be walking sticks or route marker stakes, and Iron Age, 4th–2nd century BC (Curdy and Nicod 2020).

Another recent notable discovery near the Col Collon was a sculpted wooden, human-like, object which was discovered by mountaineers in 1999. Like many regional glacial archaeological finds, this object, dated to the Iron Age, 2nd–1st century BC. It was collected and not reported to authorities and spent the last ~20 years on the wall of a mountaineer’s home (Curdy and Nicod 2020). Unfortunately, this is not a unique circumstance as most glacial archaeological finds are discovered by non-experts. However, the situation is a reminder that a concerted effort should be made to educate mountain-goers about the importance of archaeological retrieval in high altitude environments.

Recent archaeological finds from modeled locations: Col de la Forcle

Col de la Forcle, located on the northern border of Valais in the Bernese Alps was designated as a pass of interest after a GIS least cost paths investigation (Curdy, Lugon, and Rogers 2019). Pointed wooden marker poles from the Roman Period, 1st–3rd century AD were discovered on the margin of a disappearing ice patch called “Glacier de

la Forcle” located at this site (Curdy, Gubler, and Hafner 2021). Ongoing investigations show that these wooden marker poles were originally about 1.2 m long with carefully crafted tips and ends.

Integrating citizen scientists

In the Canton of Valais, glaciers are melting at alarming rates. For this reason, it is necessary to establish a coordinated response among Alpine heritage institutions of neighboring countries and involve non-archaeologists in the discovery, collection, and preservation of archaeological items located in high melt areas. In 2018, Ralph Lugon developed a participatory science project to mobilize citizens who frequent high-altitude regions. The core of the project was the development of an application to communicate georeferenced data to the cantonal authority. During the summer of 2021, the Cantonal Office of Archaeology of Valais (Canton du Valais 2022) launched this participatory science project. The application, called *IceWatcher*, has been made freely available for iOS and Android devices (Figure 2). This application allows users to follow a standardized procedure to photograph their discoveries, then transmit this georeferenced information to the authorities, who decide whether to intervene in the field or not. The application, created by Swiss company Biolevision sàrl based on iNaturalist (iNaturalist 2022), also allows hikers and mountaineers to communicate and share their archaeological observations on a dedicated platform. Since last year (2021), the app has solicited approximately 15 announcements of archaeological finds near Valais glaciers. About half of those announcements are related to archaeological materials, and these reports are being individually investigated. This is an interesting and critical first step in soliciting citizen scientists in high altitude environments to support glacial archaeology. With increased melt rates and decreased archaeological resources, citizen scientists may prove to be the most promising method for locating and protecting cultural heritage at high altitudes.

References

- Canton du Valais. 2022. “Archéologie Glaciaire.” <https://www.vs.ch/web/archeologie/archeologie-glaciaire>.
- Curdy, P., R. Gubler, and A. Hafner. 2021. “Gletscherfunde in Der Schweiz.” In *Gletscherarchäologie: Kulturerbe in Zeiten des Klimawandels*, edited by T. Reitmaier. Archäologie in Deutschland, special issue 21(2), 39–48. Darmstadt: wb Theiss.
- Curdy, P., R. Lugon, and S.R. Rogers. 2019. “Glacial Archaeology in the Central-Western Alps. From Casual Finds to Planned Research Projects.” In *Prehistory and Protohistory in Mountain Environment: Discoveries and Territorial Research, Protection and Enhancement*, edited by G. Beruti, 32–34. Turin: Museo Nazionale Della Montagna.
- Curdy, P., and P-Y. Nicod. 2020. “An Enigmatic Iron Age Wooden Artefact Discovered on the Col Col-lon (3068 m a.s.l., Évolène, Ct. Valais / CH).” *Archäologisches Korrespondenzblatt* 50(4): 497–512. <https://doi.org/10.11588/ak.2020.4.82364>.
- Eschmann Richon, M. 2014. “Cols Secondaires Des Alpes Valaisannes, Entre Le Col de Cleuson et Le Griespass.” *Vallesia* 69: 453–521.
- IceWatcher. 2022. “IceWatcher.” <https://apps.apple.com/us/app/icewatcher/id1575465367>.
- iNaturalist. 2022. “iNaturalist.” <https://www.inaturalist.org/>.
- Rogers, S.R. and P. Curdy. 2015. “Least Cost Path Analysis for Predicting Glacial Archaeological Site Potential: Scale and Parameter Investigations.” In *Predicting Prehistory: Predictive Models and Field*

- Research Methods for Detecting Prehistoric Contexts*, edited by L. Sarti and G. Pizziolo, 49–64. Florence: Museo e Istituto Fiorentino di Preistoria.
- Rogers, S.R., P. Curdy, M. Eschmann-Richon, and R. Lugin. 2018. “Glacial Archaeology in the Pennine Alps, Switzerland/Italy, 2011–2014.” *Journal of Glacial Archaeology* 3 (8): 27–41. <https://doi.org/10.1558/jga.33530>.
- Rogers, S.R., C. Collet, and R. Lugin. 2014. “Least Cost Path Analysis for Predicting Glacial Archaeological Site Potential in Central Europe.” In *Across Space and Time. Computer Applications and Quantitative Methods in Archaeology (CAA). Proceedings of the 41st International Conference, Perth, Australia, March*, edited by A. Traviglia, 25–28. Amsterdam: Amsterdam University Press.
- Rogers, S.R., M. Fischer, and M. Huss. 2014. “Combining Glaciological and Archaeological Methods for Gauging Glacial Archaeological Potential.” *Journal of Archaeological Science* 52 (12): 410–20. <https://doi.org/10.1016/j.jas.2014.09.010>.
- SNSF. 2022. “P3 Research Database, Project 130279.” <https://data.snf.ch/grants/grant/130279>.

Glacial Archaeology in Inner Asia

William T. T. Taylor

University of Colorado

Perhaps nowhere is the future of glacial archaeology more promising or more uncertain than in the high mountains of Inner Asia. This vast region stretches from the Tibetan Plateau and the grand Himalaya in the southeast, westward through the high Hindu Kush, Pamir, and Tian Shan of Central Asia, and northward through the high Sayan-Altai mountain chain separating the steppes from Siberia. Vast regions of the interior of the Asian continent are defined by the geology and ecology of high mountain zones. In most dry regions, rainfall and snowpack make high mountains into ecological “hotspots” with greater biological productivity that sustain plant and animal communities through hot summer months. Mountains in Inner Asia rarely function as barriers but instead serve as cultural corridors, historically facilitating travel and trade via mountain passes and across the continent through vast networks including the Silk and Tea-Horse Roads. In many areas, even extreme altitudes have been occupied since the earliest chapters of human history.

Despite the significance of mountain corridors in the broad trajectory of the human story in Asia, many of these areas are poorly represented in the archaeological record. Most historical texts were written by lowland agricultural civilizations of areas like the Tigris/Euphrates, Indus, or Yangtze, but fewer records survive from the influential cultures and kingdoms of the high country. Many areas suffer from underrepresentation in the archaeological record, where fieldwork can be difficult, expensive, and time intensive. Cultural factors such as the ubiquity of mobile pastoralism compound this issue further, because these cultures often leave behind shallow archaeological deposits and organic material culture does not preserve well in these depositional contexts.

Glacial archaeology is poised to make a significant impact on archaeological narratives in Inner Asia. While the discipline remains in its formative stages across most



Figure 1. An argali sheep skull exposed by melting ice in the Mongolian Altai alongside other important artifacts rarely preserved in other Inner Asian archaeological contexts.

of the region, early results have been extremely promising. For example, in western Mongolia our recent research reveals that melting mountain ice contains a record of human activity at high altitude, and some ice patches have produced artifacts spanning the last four millennia. Insights gained from melting ice are filling gaps that can't be filled elsewhere, and reveal alpine hunting of big game including argali sheep was a core aspect of early herding life. Furthermore, some of these sites provide the only well preserved examples of Bronze Age projectile technology.

Long term scientific records of plant and animal activity and paleoenvironmental data are also helping researchers generate interdisciplinary scientific studies of human-environmental relationships in Asian mountain zones. Organic materials from the ice also provide opportunities for detailed biomolecular analysis, including ancient DNA study of domestic animal remains, or protein based identification of animal tissues used in artifact production, such as sinew lashing or bone projectiles.

These early research efforts demonstrate the potential of glacial archaeology to unlock the secrets of mountain prehistory in Asia, but this potential is being threatened and lost as a result of global warming. Precious few archaeological initiatives are working to conduct glacial archaeological fieldwork and modern nation-state boundaries in this region are often drawn along high-altitude topographic lines, often dividing research and ecological zones along politically contentious or even dangerous military fronts. Even under ideal conditions, conducting research in Inner Asian mountain areas means navigating cultural, linguistic, and jurisdictional boundaries while also working with limited infrastructure (horses instead of helicopters). As noted by Pilø (this Forum), many massive mountain zones have never been archaeologically investigated, much less comprehensively surveyed and archaeological research in the Mongolian Altai has barely begun. Furthermore, many of Asia's most

promising archaeological zones occur in developing nations that fall outside of arctic and subarctic zones eligible for cryosphere-oriented funding, making it difficult to acquire and sustain large long term research programs. In recent years, the COVID-19 pandemic and conflicts in areas like Afghanistan, Ukraine, and Central Asia have hampered the ability for international teams to coordinate and collaborate. Ice loss in most glaciated areas of Inner Asia is proceeding at a shocking pace, threatening both the viability of modern lifeways and the rare, important cultural and ecological records held within glaciers and ice patches.

The High Arctic

Climate Change and the Continued Preservation of the Arctic Archaeological Record

Jørgen Hollesen

National Museum of Denmark

Over the past few decades, climate change has accelerated erosion and biodegradation at many heritage sites and archaeological resources in the Arctic. In the coming decades, I fear that the combined effects of rising air temperatures, fluctuations in precipitation, melting glaciers and rising sea levels will have wide ranging implications for the continued preservation of archaeological sites and materials in the Arctic (Hollesen *et al.* 2018; Fenger-Nielsen *et al.* 2020)

Permafrost thaw is one of the consequences of a warming climate in the Arctic. The increasing thickness (depth) of the active layer (the upper part of the soil that thaws



each summer) is exposing long-frozen deposits to accelerated erosion, wet/dry and freeze/thaw cycles, and microbial activity (Figure 1). These changes may expose hitherto well-preserved archaeological layers and artefacts to accelerated chemical and physical degradation (Hollesen *et al.* 2015; Matthiesen *et al.* 2013).

Increasing temperatures and favorable growing season conditions also lead to more and denser vegetation with deeper roots (Figure 2)

Figure 1. A kitchen midden with thick layers of bones, food remains, worn out tools and other refuse is found at the site Qajaa in West Greenland. The erosion of earlier times has cut a section down through the midden, so one can see its whole history exposed layer by layer. Investigations and model results have shown that in a worst case scenario up to 60% of the middens's organic content could potentially vanish within the next 80 years (Hollesen *et al.* 2015). Photo: Jesper Stub Johnsen, National Museum of Denmark.

that not only impact the surface energy balance, the nutrient cycling and soil hydrology, but may also cause physical damage to buried artefacts and disturb and destroy site layering and stratigraphy (Andersen *et al.* 2020; Matthiesen *et al.* 2020; Prendin *et al.* 2022).



Figure 2. Arctic archaeological sites are “hotspots” of vegetation and plant nutrients. Root damage and overgrowing is happening at many of the inland sites in Greenland. Comparison of photos between 1932 (upper) and 2017 (lower) shows a clear increase in the presence of Northern willow (*S. glauca*) at the famous Norse site Ujarassuit (Anavik). (Photo 1932: Roussel, National Museum of Denmark and Photo 2017: Roberto Fortuna, National Museum of Denmark).

Changing precipitation patterns can have multiple effects. For example, an increase in precipitation and more melt water from snow, can lead to increased erosion; whereas less precipitation may cause drying of the ground and an increase in the amount of oxygen that diffuses into the ground. These factors impact the microbial decomposition of organic materials (Hollesen *et al.* 2017; Hollesen *et al.* 2019).

Finally, the combination of sea level rise, longer periods of open water due to sea ice decline and more frequent storms is expected to intensify erosion of the Arctic coast line (Lantuit *et al.* 2012). Coastal erosion poses a widespread threat to many archaeological sites in this region due to the predominantly coastal lifeways of Arctic people. The permafrost coasts of North and Northwest Alaska and the western Canadian Arctic are characterized as one of the largest areas of high sensitivity shoreline in the circumpolar Arctic (Lantuit *et al.* 2012). While not a new phenomenon in this area, coastal erosion is currently widespread and adversely affecting the archaeology in the region (Friesen 2015; O'Rourke, 2017)

Accessibility to the Arctic is also improving as a direct consequence of climate change (increasing seasonal sea ice melt). Tourist visits to archaeological sites are anticipated to increase dramatically in the coming decades, especially at the most famous and significant sites. Despite the broad attention that Arctic sustainability and climate change has garnered in recent years among the international scientific community, there is still a desperate need for knowledge regarding how to facilitate sustainable tourism at these very fragile cultural resources. The impacts of uncontrolled or poorly planned tourism on archaeological sites have been well documented in other parts of the world, but there is limited information as yet from the Arctic.

Melting ice, thawing permafrost, and coastal erosion are exposing Arctic archaeological sites to potential damage not just from tourists, but also from commercial and non-commercial collectors. This includes some members of local Arctic communities, who collect artefacts and other archaeological resources found on the ground surface or at eroding soil faces at the shoreline. While these activities are often legal (Hollowell 2011), they are sometimes illegal. It should be expected that there will be an increase in this type of collection as erosion of coastal archaeological sites accelerates and melting ice and thawing permafrost exposes more remains. However, there is also the danger of large-scale plundering of archaeological resources as has been reported in Northeast Siberia. Here, high pressure hydraulic pumps have been used to “mine” concentrations of mammoth remains, which were accumulated at kill and butchery sites such as Berelekh, Yana and Buor-Khaya (Pitulko 2014).

So far, very little has been done to develop methods for mitigation, meaning that at present, excavation may seem to be the only applicable solution for vulnerable archaeological deposits at risk of degradation. Excavations in permafrost regions are expensive and time consuming and archaeologists are already overwhelmed. As the climate continues to change, this situation undoubtedly will get worse. There is no recourse to “developer pays” strategies for mitigation when natural processes are causing the damage. Most jurisdictions do not have designated funds or programs for archaeological mitigation. This must change if we are going to respond to the problem of natural threats to heritage in a serious and efficient manner.

References

- Andersen, E.A.S., A. Michelsen, R. Fenger-Nielsen, J. Hollesen, P. L. Ambus and B. Elberling. 2020. "Nitrogen isotopes reveal high N retention in plants and soil of old Norse and Inuit deposits along a wet-dry arctic fjord transect in Greenland." *Plant Soil* 455: 241–255. <https://doi.org/10.1007/s11104-020-04683-1>
- Fenger-Nielsen, R., B. Elberling, A. Kroon, A. Westergaard-Nielsen, H. Matthiesen, H. Harmsen, C. K. Madsen, M. Stendel and J. Hollesen. 2020. "Arctic archaeological sites threatened by climate change: A regional multi-threat assessment of sites in south-west Greenland." *Archaeometry* 62(6): 1280–1297. <https://doi.org/10.1111/arc.12593>
- Friesen, T. M. 2015. "The Arctic CHAR Project: Climate change impacts on the Inuvialuit archaeological record." *Les nouvelles de l'archéologie* 141: 31–37. <https://doi.org/10.4000/nda.3098>
- Hollesen, J., M. Callanan, T. Dawson, R. Fenger-Nielsen, T. M. Friesen, A. M. Jensen, A. Markham, V. Martens, V. V. Pitulko and M. Rockman. 2018. "Climate change and the deteriorating archaeological and environmental archives of the Arctic." *Antiquity* 92: 573–586. <https://doi.org/10.15184/aqy.2018.8>
- Hollesen, J., H. Matthiesen and B. Elberling. 2017. "The impact of climate change on an archaeological site in the Arctic." *Archaeometry* 59: 1175–1189. <https://doi.org/10.1111/arc.12319>
- Hollesen, J., H. Matthiesen, R. Fenger-Nielsen, J. Abermann, A. Westergaard-Nielsen and B. Elberling. 2019. "Predicting the loss of organic archaeological deposits at a regional scale in Greenland." *Scientific Reports* 9: 9097. <https://doi.org/10.1038/s41598-019-45200-4>
- Hollesen, J., H. Matthiesen, A. B. Møller and B. Elberling. 2015. "Permafrost thawing in organic Arctic soils accelerated by ground heat production." *Nature Clim. Change* 5: 574–578. <https://doi.org/10.1038/nclimate2590>
- Lantuit, H., P.P. Overduin, N. Couture, S. Wetterich, F. Aré, D. Atkinson, J. Brown, G. Cherkashov, D. Drozdov, D. L. Forbes, A. Graves-Gaylord, M. Grigoriev, H. W. Hubberten, J. Jordan, T. Jorgenson, R. S. Ødegård, S. Ogorodov, W. H. Pollard, V. Rachold, S. Sedenko, S. Solomon, F. Steenhuisen, I. Streletskaya and A. Vasiliev. 2012. "The Arctic Coastal Dynamics Database: A New Classification Scheme and Statistics on Arctic Permafrost Coastlines." *Estuaries and Coasts* 35: 383–400. <https://doi.org/10.1007/s12237-010-9362-6>
- Matthiesen, H., R. Fenger-Nielsen, H. Harmsen, C. K. Madsen, and J. Hollesen. 2020. "The impact of vegetation on archaeological sites in the low Arctic in light of climate change." *Arctic* 73(2): 141–152. <https://doi.org/10.14430/arctic70248>
- Matthiesen, H., J. B. Jensen, D. Gregory, J. Hollesen and B. Elberling. 2014. "Degradation of archaeological wood under freezing and thawing conditions—effects of permafrost and climate change." *Archaeometry* 56: 479–495. <https://doi.org/10.1111/arc.12023>
- O'Rourke, M.J.E. 2017. "Archaeological site vulnerability modelling: The influence of high impact storm events on models of shoreline erosion in the western Canadian Arctic." *Open Archaeology* 3: 1–16. <https://doi.org/10.1515/opar-2017-0001>
- Pitulko, V. 2014. "Potential impacts on the polar heritage record as viewed from frozen sites of East Siberian Arctic." In *International Polar Heritage Committee of ICOMOS conference 2014: the future of polar heritage—programme and book of abstracts*, Copenhagen, edited by J. Bickersteth, N. Watson, M. Frisen and J. Hollesen, 77–80. Copenhagen: National Museum of Denmark
- Prendin, A. L., S. Normand, M. Carrer, N. Bjerregaard Pedersen, H. Matthiesen, A. Westergaard-Nielsen, B. Elberling, U. A. Treier and J. Hollesen. 2022. "Influences of summer warming and nutrient availability on *Salix glauca* L. growth in Greenland along an ice to sea gradient." *Scientific Reports* 12(1): 3077. <https://doi.org/10.1038/s41598-022-05322-8>