Ice on the Edge: Methods and Recommendations for Conducting Ice Patch Surveys in Rocky Mountain National Park

by

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Prepared for
National Park Service
Rocky Mountain National Park
Estes Park, Colorado

Under the provisions of
Permit Nos. 06-ROMO-01 (expires 12/31/10)
and ROMO-2010-SCI-0037 (expires 12/31/10)

May 2010

Abstract

Paleobiological discoveries have been made in association with melting perennial snow and ice patches in the Colorado Front Range, including in Rocky Mountain National Park. Studies elsewhere in the Rocky Mountains, e.g., the Greater Yellowstone area, have produced archaeological materials, including organic tools, as well as paleobiological materials. Because perishable artifacts rarely occur at prehistoric archaeological sites, ice patches provide an important context for the recovery of this nearly invisible element of hunter-gatherer technology. As a result of their completeness and unique ecological area of recovery, they illuminate the systemic context in which the tools functioned. This report and associated GIS data provide Rocky Mountain National Park with methods and recommendations for conducting ice patch surveys in the Park. Associated GIS data identifies 23 ice patches with the highest archaeological potential in the Park.

Acknowledgments

Numerous individuals have contributed to this project, including Cheri Yost, Judy Visty, Tim Burchett, and Karen Waddell in Rocky Mountain National Park; Jim Bradford and Jan Orcutt in the National Park Service's Intermountain Region Office; and Pei-Lin Yu and Kathy Tonnessen at the Rocky Mountain Cooperative Ecosystem Studies Unit. James Benedict, Center for Mountain Archaeology, and colleagues at the Institute of Arctic and Alpine Research (INSTAAR) at the University of Colorado-Boulder have helped me to formulate many of the ideas, but any errors in logic are my own. The nature of this research is speculative and the results are not guaranteed. The suggestions made herein and in the attached GIS file represent good faith efforts – should our environment continue to warm and the ice in the identified research areas continue to melt, I sincerely hope surveys of the identified areas will either be productive or leave us with a clear conscious.

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Introduction

As the Earth's climate warms, archeological and paleobiological materials are being discovered in association with destabilized and melting perennial snow and ice resources around the world (e.g., Dixon et al. 2005; Farnell et al. 2004; Finstad 2007; Hare et al. 2004; Lee et al. 2006; Müller et al. 2003). Although artifacts have been found in association with glaciers, in North America they have primarily been discovered in association with static snow banks, or "ice patches," solidified through the process of nivation.[1] Ice patches characteristically exhibit little internal deformation or movement, and may contain ancient ice that, unlike glaciers, is kinetically stable and preservative.

Some ice patches were used prehistorically by Native Americans to hunt game animals, e.g., big horn sheep and bison that were attracted to the locations. Preserved organic artifacts that might result from such encounters include arrows, darts, sinew lashing and fletching, as well as basketry, clothing, and cordage. The stable ice in these features retards decay and has kept otherwise perishable materials suspended in virtually unaltered states for millennia; however, global warming is destabilizing this once protective mantle of snow and ice. Once an artifact or specimen is released from the snow/ice, arrested taphonomic processes resume and organic components rapidly decompose.

Permanent ice patches persist as a result of drifted windblown snow that survives the summer months due to topographic shading and a "four-to-eight-fold concentration of snow by wind in east- and northeast-facing hollows" (Outcalt and MacPhail 1965); they are not massive enough to become glaciers. As used here, the term "ice patch" does not refer to the highest elevation snow and ice that occurs along jagged arêtes well above timberline or the small glaciers and glacierettes that occupy steep-sided cirques; rather, it refers to the lowest elevation permanent snow and ice that forms along gentle topography downwind from snow catchments (Figure 1). The highest potential ice patches tend to lie in the wind shadow, or lee, of mesas or hills.

[1] The freeze/thaw cycle in which fallen snow gets compacted into firn/névé or ice (AIG 1957).

Figure 1: Representative ice patches in Rocky Mountain National Park with ideal topographic characteristics (Google Earth screen capture, NAD 83, Zone 13, 433414E, 4472910N, elev. 3500 meters; August 2009).

This document provides a rationale for surveying areas of snow and ice in Rocky Mountain National Park (ROMO) for archaeological materials in association with permanent snow and ice. The methods described here have applicability beyond the Park. Heretofore, only paleobiological materials have been recovered within the Park (Benedict et al. 2008; Lee and Dixon 2006) and vicinity (Graham 2006; Lee et al. 2006). Other National Parks have either conducted or are conducting similar studies, including Glacier National Park (Kelly and Lee 2010), Yellowstone National Park (Lee 2009), Denali National Park (Lee 2010) and other parks in Alaska, e.g., Wrangell St. Elias (Dixon et al. 2005). Ice patch research captures public imagination and is readily amenable to discussions of prehistory as well as other timely issues including climate variability.

Ice Patch Identification

The techniques used to identify permanent ice patches in ROMO were adapted from those used to find similar features in Denali and Yellowstone National Parks (Lee 2010,

2009) and on the Custer, Gallatin and Shoshone National Forests in Montana and Wyoming (Lee 2007a-c, 2008a-b). Several factors appear to influence an ice patch's potential to contain archeological material, including 1) relative isolation of ice patches from one another, which seems to concentrate activity toward a given location; 2) proximity to lower elevation, ice patch-free country; and 3) relative ease of access, e.g., proximity to human and animal travel corridors (passes). Depending on the degree of melt and local conditions, in some years ice patches can appear to have a black halo, particularly on their downslope sides, due to the presence of windblown and other organic material (e.g., animal feces).

The ice patch identification process involves using virtual globes (VG) and other sources of publicly available satellite and aerial imagery to scan a given area for snow and ice exhibiting the characteristics outlined above and in the introduction. VGs, such as Google Earth (earth.google.com) and NASA's World Wind (worldwind.arc.nasa.gov) play a significant role in this endeavor; however, other online utilities such as Flash Earth (flashearth.com) and proprietary imagery can also be used.

VGs can easily manipulate complex geospatial data in three dimensions to maximize topographic relief and to focus on the northeast-facing exposures where ice patches persist. At minimum, before going into the field to conduct a survey, it is advisable to examine the prospective survey area for ice patches meeting the above criteria using a VG.

VGs have different strengths. For example, World Wind provides seamless LandSat imagery and seamless, 1 meter resolution, ortho-rectified digital photography draped over a digital elevation model (DEM) as well as USGS 7.5' series quadrangle maps. Google Earth uses a similar DEM, and has more regularly updated color imagery, as well as different search capabilities (e.g., by UTM) and the ability to set virtual place marks to flag potential areas for survey. Google Earth version 5.0 and higher has a "time slider" feature that allows the user to toggle between images from different years and seasons. There are locations in ROMO where images from five or six different years and seasons are available (Figure 2).

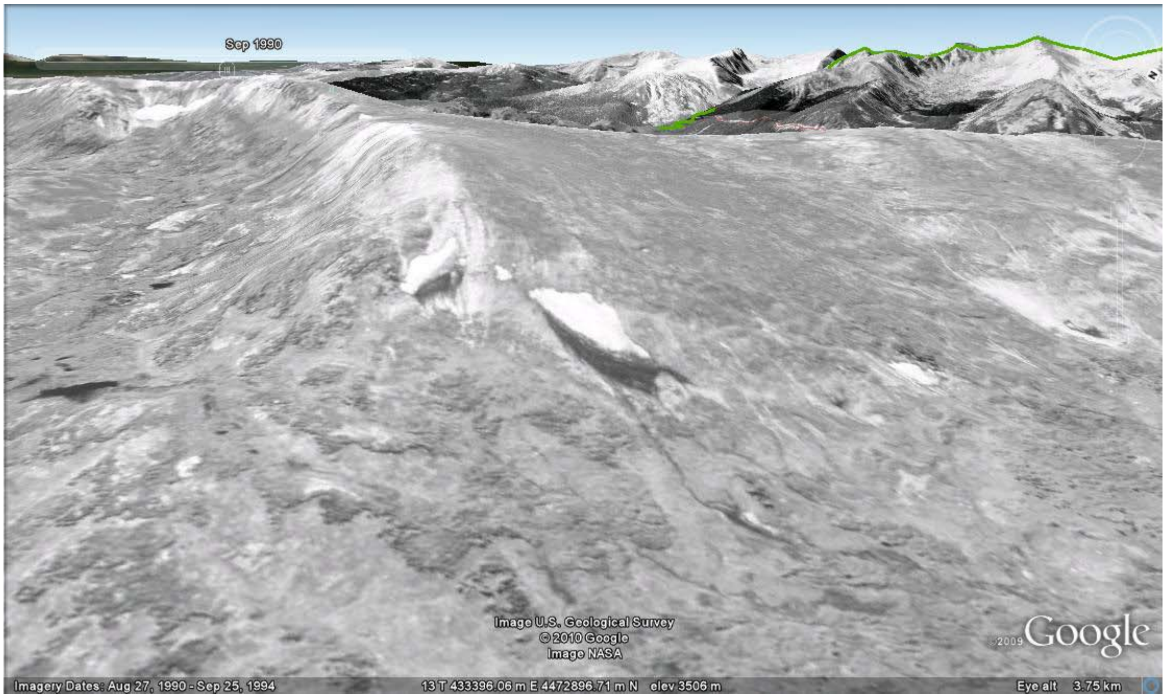

Figure 2: Rocky Mountain National Park ice patch with black, organic "halo" on downslope side. This image of the same ice patch as seen in Figure 1 was taken in September 1990 (Google Earth screen capture, NAD 83, Zone 13, 433414E, 4472910N, elev. 3500 meters; September 1990).

Following the identification of probable ice patches using VGs, other sources of imagery can be consulted, including National Aerial Photography Program (NAPP) imagery, to determine if the ice patches under consideration are permanent features. All of the ice patches identified in the shape file (ROMO_ICE_ARCH) submitted to ROMO as a part of this report were present in the imagery consulted.

Ranking Resources, Timing Surveys and Staying on Target

After making the initial selection of survey locations it is parsimonious to rank the ice patches to maximize the survey window. Invariably, survey will need to occur in the latter part of the summer and early fall, before significant snowfall occurs. Survey is also constrained by preceding years of seasonal snowmelt and precipitation. Consequently, it is important to be forthright about the longitudinal nature of the study. Ranking the prospective ice patches is also advisable because of access issues. Many Parks, including ROMO, are managed as wilderness; given the limited survey window – maybe 10 to 15 days – and other constraints, it is advisable to target the highest potential ice patches first given the possibility that subsequent years may be less conducive to survey (Figure 3). The early 1990s and 2000s presented ideal conditions for documenting archaeological and paleobiological material in association with ice patches. Alternately, the heavy snows of 2007/2008 allowed ROMO ice patches to grow.

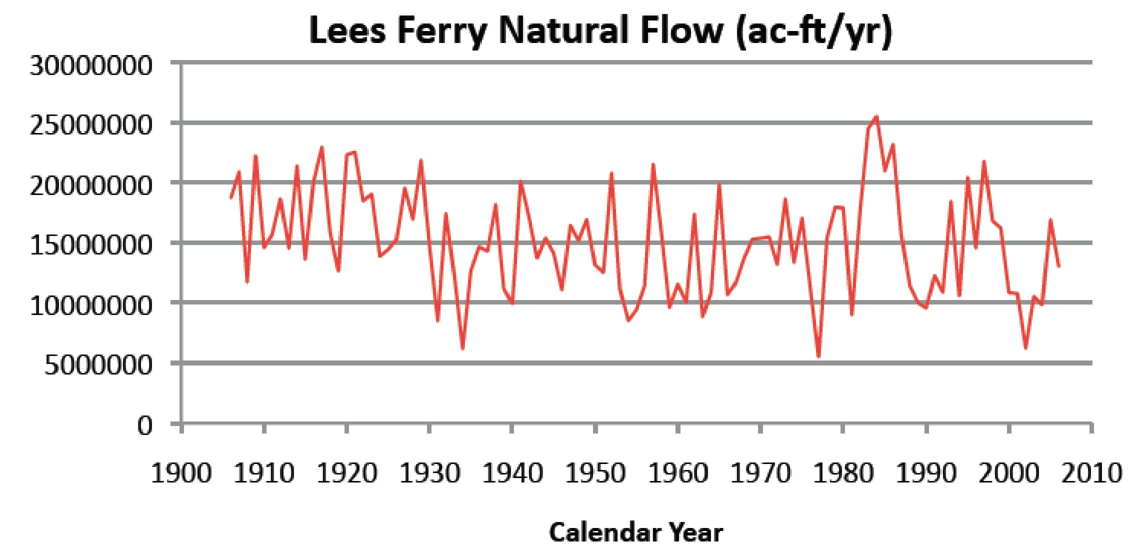

Figure 3: Proxy for ice patch melting. The natural flow rate of the Upper Colorado Basin can serve as a proxy for productive ice patch survey years (Figure compiled by Lesleigh Anderson, USGS, using published data).

Before going into the field it is advisable to print out VG images of the target area to help with orientation, and to use as the basis for a site map if necessary. It is also wise to load reliable coordinates into a GPS device to ensure you reach your intended destination(s). This is important because other non-permanent snow fields can be present in the area (Figure 4).

Repeat visitation of select ice patches, such as those that will be visited for the first time this year, will form the basis for gauging snowmelt in future years. Comparisons with dated photos such as those available in Google Earth can also provide a sense of the relative melting occurring in a given year. For purposes of predicting a major melt year, a resource such as the Natural Resources Conservation Services' (NRCS) Colorado Snowpack Maps can provide an early season gauge for potential melt; if minimal snow is on the ground in the spring, chances are the ice patches could melt significantly that year.[2] Figure 5 illustrates the difference between a low snowpack (2002) and high snowpack years. Numerous paleobiological samples were reported in 2002; none were reported in 2008.

Figure 4: Impermanent snow fields. None of the snow fields in this photo taken in Yellowstone National Park in early September 2008 are permanent (Lee 2009).

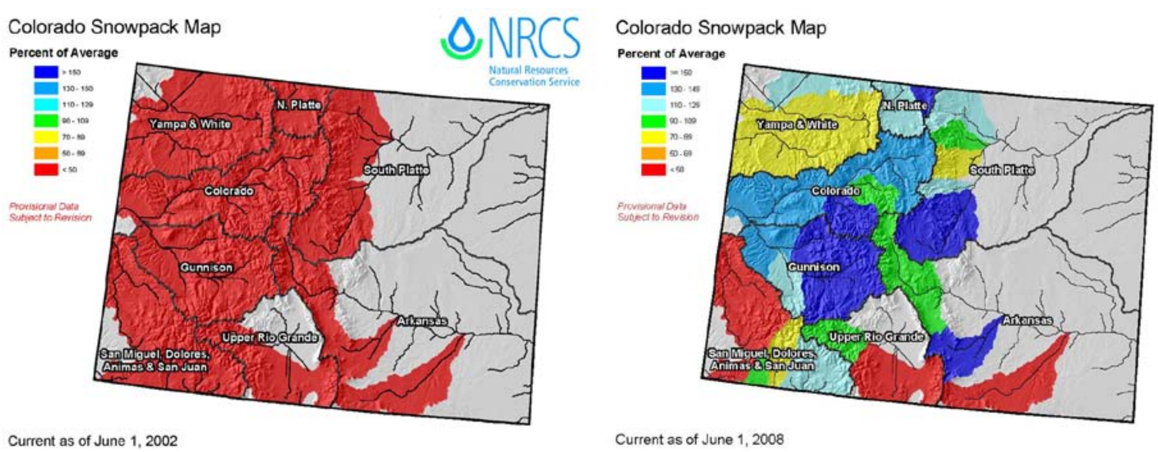

Figure 5: Colorado Snowpack maps; low snowpack vs. high snowpack years. Images from Colorado Natural Resources Conservation Service.

[2] Colorado Natural Resources Conservation Service
http://www.co.nrcs.usda.gov/snow/snow/state/current/monthly/maps_graphs/getsnomap.html

Equipment and Stabilization Techniques

Given the remote location(s) where most ice patches exist, hiking is a necessity. To maximize data gain for each trip, be sure to bring your GPS device and digital camera. In order to collect and transport fragile artifacts (e.g., arrow shafts), use lightweight portable materials such as "Coroplast" fluted plastic board (www.coroplast.com). Plastic board flexes slightly and can help to cushion artifacts during transport. It can also be scored and folded to make archival boxes (Figure 6). It is recommended that you carry at least one ca. 36" by 24" sheet folded on the long axis. Artifacts can be held in place with rolled cotton bandages. It is recommended that you carry three 2" x 60" rolls. To stabilize an artifact, cut the board several inches longer and wider than the size of the artifact being collected. Score the edge of the board and "web" the artifact onto the board using the bandages. Other supplies include a variety of Ziploc bags, garbage bags and strips of unbleached cotton muslin to shore up splitting artifacts. If an organic artifact is dry, keep it dry. If it is wet, consider wrapping it in plastic after field stabilization for transport to a freezer (see conservation below).

Figure 6: Stabilized artifacts and paleobiological samples. The artifacts and plaeobiological samples in this photo were collected at melting ice patches in Montana (Photo: Craig M. Lee, 2009).

Locating and Recording Artifacts

Artifacts are most frequently encountered along the downslope margin of the ice patch and in the off-ice area immediately below the ice patch - the forefield. Artifacts collect here as they slide off the ice and/or are transported by fluvial action. If an ice patch has a large, relatively low-slope surface, artifacts can occasionally be found directly on the ice. In these instances the artifact will usually be in association with other organic material, including animal feces and windblown detritus.

Ice patches with dark staining in late summer and early fall hold the most potential for discoveries. The runoff channels below ice patches are another location where cultural material can be recovered. In general, the further away from the ice an artifact is encountered, the more degraded it will be as a result of exposure to water, wind and sun. If you find an artifact, photograph it in situ with a scale and take several overview/context photos. Because organic material is a lag deposit, be sure to record GPS points for every discovery.

Paleobiological Materials

There can be a surprising volume of paloebiological material encountered at an ice patch. Everything from large timber trees to dead birds and feces. Consequently, it is important to have a sense of what your research goals are before you go into the field. If you are looking for archaeology, it is not necessary, practical, or even feasible to collect every piece of wood or bone that you encounter. Do your best to ascertain if the material has cultural significance (e.g., Is that bone spirally fractured? Is that piece of wood purposefully shaped?). If you do not find anything cultural but you discover paleobiological material, consider collecting a few small samples for radiocarbon dating. If the material is old, it might help make your case for future efforts. Share your observations as widely as possible (e.g., with biologists, ecologists, rangers, contacts at local universities, etc.).

Other field considerations

When documenting an area of permanent ice, take overview photos of the location from far enough away to allow the extent of the ice to be compared year-to-year (Figure 7). Important: note the GPS coordinates of the location where the context photographs were taken, as well as the cardinal direction, time and date of the photo. Record the presence of windblown organic material, animal feces, etc., present at the ice patch. Take a few context photos as well. Look for stone alignments and/or breast works/hunting blinds, as well as chipped stone artifacts. Keep an open mind about what you might encounter and expect that preservation will be variable. If you are at or above tree line and you encounter a piece of wood consistent with an arrow or dart shaft but see no obvious modifications (e.g., nock or hafting elements), consider collecting it to provide a contextual basis for subsequent discoveries. Appendix B: Field Form for Recording Rocky Mountain National Park Ice Patches may be useful to prompt the collection of certain data, but the categories identified are not exhaustive.

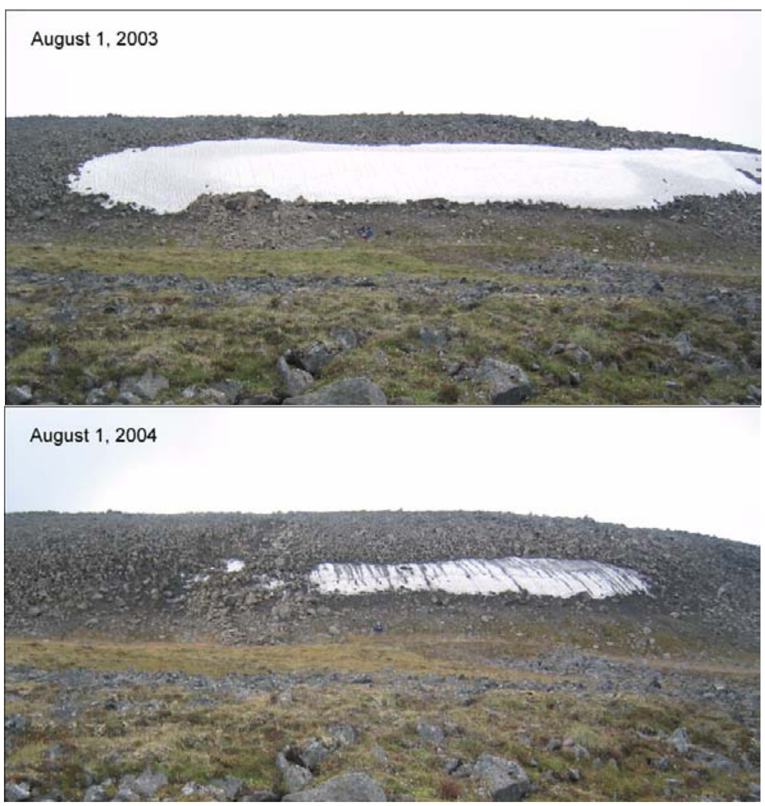

Figure 7: The dynamic nature of ice patch extent. The comparative photos above were taken in Wrangell-St. Elias National Park (Photos: William Manley).

Post-field considerations

If the artifacts are dry, put them into a safe space. Try to support them with shims if they are warped, e.g., an arrow shaft that may be curved as a result of warping should be supported in multiple places. Wet organic artifacts can be dried, but there is a risk of warping and splitting. Some alteration is inevitable, but best practice to minimize damage should be followed: If the artifact is splitting, wrap it snugly with fabric strips such as Tyveck or unbleached muslin (see Figure 6). Place the wet artifact into a bag or container with a relatively small opening and put it in the freezer. This will allow the moisture to slowly evaporate from the artifact through ablation. Depending on how wet the object is, you can modify how well-wrapped it is in order to change the rate of ablation.

If the artifact is too large to fit in your available freezer, you can create a make-shift humidification chamber. Put the artifact in a moisture-proof case, such as an under-the-bed Rubbermaid storage container. Ensure the artifact is well supported, and put a small bowl of water into the container. Put the lid on but leave it slightly ajar by 1-2 cm. Note: If you recover a leather artifact (e.g., a moccasin) a professional conservator will need to assist you with stabilization. Not all conservators are qualified to do this. Contact an Objects Conservator at a major museum such as the Denver Museum of Nature & Science or contact Craig.Lee@colorado.edu and I will share my most current contact information. You can also check http://instaar.colorado.edu/ice_archaeology for additional advice. In the meantime, keep the artifact frozen!

Target Areas for Rocky Mountain National Park

Ideally, it is best if a knowledgeable person can be present during the collection of archaeological and/or paleobiological materials; however, it is possible to envision a variety of scenarios in which backcountry personnel might encounter something unexpectedly. For planned assessments of specific ice patches, field personnel should inform the Museum Curator they will be in the field so the curator can be prepared for receiving materials. General advice for Park staff regarding ice patch discoveries might include the following:

1) Keep an eye out for ice covered with organic material, or for ice with an extensive concentration of organic material below it. If you encounter this situation, examine the organic rich area and vicinity for wooden tools, e.g., dart and arrow shafts, chipped stone projectile points, or paleontological/ paleobiological materials;

2) Regardless of whether anything is found, document the location with an accurate GPS waypoint and photos. Give this information to the Park Curator as soon as possible;

3) If an artifact or paleobiological sample is identified, take detailed notes of the artifact/sample location and look around for more material in the area – take numerous photos of the artifact/sample in situ;

4) If you are in an EXTREMELY REMOTE LOCATION and an artifact is in danger of theft or destruction you can collect it by carefully wrapping it in a clean bag and supporting it as best you can against a piece of cardboard or tent pole. Bring it in to Park Curator IMMEDIATELY after coming out of the backcountry;

5) DO NOT collect paleontological/paleobiological material. Notify the Park Curator of discoveries immediately and take a qualified person to the location as soon as possible.

Because discoveries can occur unexpectedly, any materials collected by a person other than the Park Curator should be delivered to the museum storage facility the same day they are collected, or at maximum the next working day. If archeological materials are recovered, Colorado site forms will need to be completed for the resources, and they will need to be entered into the NPS ASMIS system.

Following a brief statement of methods, two survey areas for the 2010 field season are presented. The report concludes with a discussion of the importance of this project relative to work being conducted elsewhere in the Rocky Mountains. An electronic appendix (Appendix A) provides the survey locations for 23 prospective ice patches in the Park with archaeological potential.

Identification of Survey Areas in Rocky Mountain National Park

The long-term trend toward melting subpolar mountain glaciers (Dyurgerov 2001, 2002; Dyurgerov and Meier 2000, 2005) is also affecting glaciers and ice patches in ROMO. The United States Forest Service's Beartooth Climate Change Project (BCCP), for which the Principal Investigator (PI) is co-PI, has identified specific years (e.g., 1987 and 1994) when significant melting occurred on ice patches in the Greater Yellowstone area (Weber 2008; unpublished data). Dated images from those years suggest that ice patches in ROMO were also retreating at that time.

Area 1

An area of permanent ice north of Mount Ida (ROMO_3) will be surveyed this year. If this area becomes one of the baseline areas for gauging snow and ice melt in the Park, it may be advisable to survey it, or at least visually inspect it from a distance, during subsequent years to gauge melt in the Park. This area is depicted in Figures 1 and 2. The ice patch has a relatively broad forefield with a shallow slope. Forefields of this nature tend to collect and retain artifacts once they melt free and slide off the face of a retreating ice patch, whereas the steep channels that occur below some ice patches in drainages tend to be swept clean by runoff. Access will be determined through consultation with knowledgeable individuals in the Park, including Cheri Yost and Judy Visty.

Area 2

An area of permanent ice (ROMO_19) along Trail Ridge Road will also be surveyed this year (Figure 8). Similar to Area 1, this ice patch has a relatively broad forefield although the slope may be steeper than in Area 1. The ice patch's proximity to the Park road system will provide good training opportunities for Park staff and volunteers. Although this area is not as promising as Area 1, its proximity to Trail Ridge Road suggests it should be assessed on yearly basis as a proxy for melt at other ice patches in the Park.

Project Implementation and Summary

In August and September 2010 the PI will train ROMO cultural resource staff on survey methods at two prospective ice patches (see GIS layer); Areas 1 and 2 and proximate ice patches. The PI will analyze any recovered objects and work with the Park Curator to ensure their long term conservation. Park staff will be able to re-visit these and other specified locations over the course of successive summers as ice melt conditions warrant.

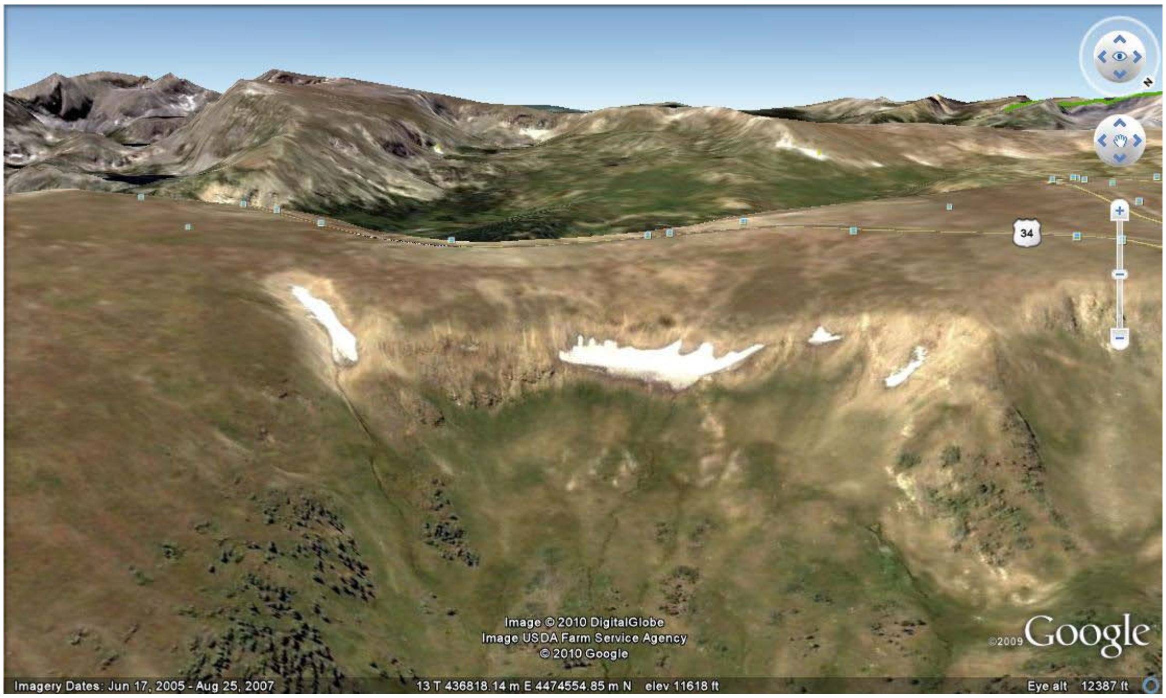

Figure 8: Rocky Mountain National Park ice patch near Trail Ridge Road.

Ice patches hold the potential to stimulate scientific inquiry ranging from the technological analyses of artifacts to paleoclimatic reconstructions. This research is important to 1) archeologists interested in material culture; 2) the general public as a tangible, local effect of global warming and as a store house of information about ancient peoples; 3) Native American groups whose cultural heritage is tied to these environments; 4) federal and state agencies with management responsibilities for these resources; and 5) scientists in allied disciplines who are interested in Earth climate systems.

Ice patch resources are at risk of vandalism (collection) and destruction by natural causes. There is an urgent need to continue systematic research at these sites and to geographically and intellectually expand the scientific potential of ice patch archeology through survey, analysis, publication and public education/outreach. The results will benefit both the park and Dr. Lee's ongoing research with ice patch archaeology.

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Appendix A: Shape File, Prospective Ice Patches for Survey in Rocky Mountain National Park (electronic – under separate cover)

Appendix B: Field Form for Recording Rocky Mountain National Park Ice Patches