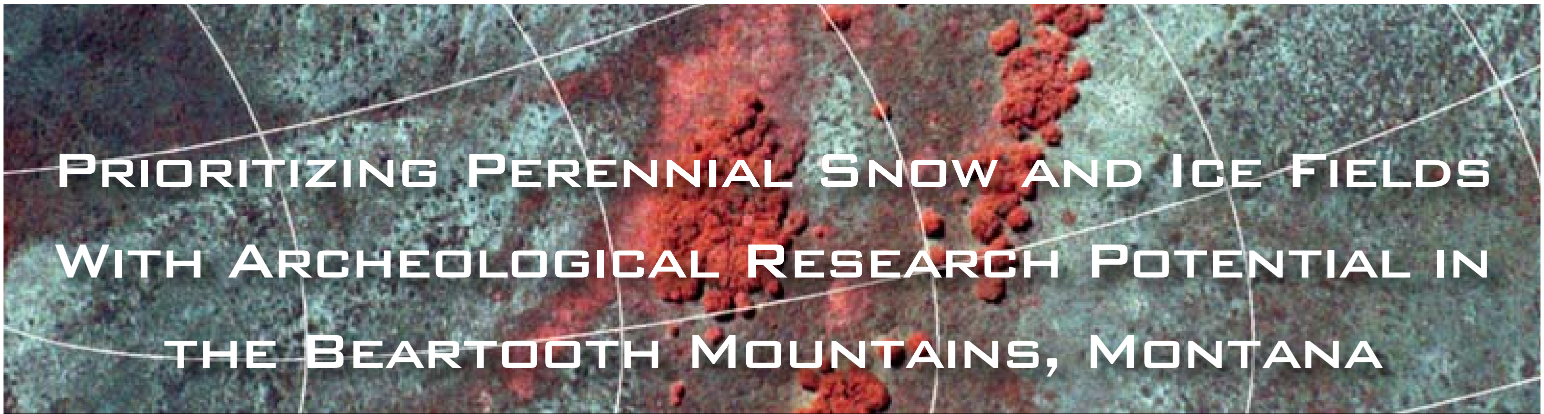

Prioritizing Perennial Snow and Ice Fields With Archeological Research Potential in the Beartooth Mountains, Montana

August 2009 **RSAC-0115-RPT2**

United States Department of Agriculture

Forest Service

Geospatial Management Office

Remote Sensing Applications Center

Abstract

The U.S. Department of Agriculture, Forest Service, Remote Sensing Steering Committee awarded funding to investigate methods to estimate the historical minimum extent of permanent alpine snowfields in the Absaroka-Beartooth Mountains and to prioritize archeological and paleobiological inventories. Two sites within the mountain range were selected for analysis. Five dates of stereo photography, spanning from 1952 to 2003, were analyzed for each site. The photos were orthocorrected in Leica Photogrammetry Suite (LPS), and the boundaries of the snowfields were digitized for each date. These boundaries were then intersected in ArcGIS to determine their minimum extent. It is assumed that any archeological and paleobiologic resources beyond the minimum extent of the snowfields have undergone deterioration and are no longer a priority for field inventory. The methodology used for this project can be cost effective in monitoring the state of semipermanent alpine snowfields and prioritizing field inventories.

Key Words

archeology, paleobiology, organic artifacts, remote sensing, Stereo Analyst, aerial photography, climate change, glaciers, Beartooth Mountains, orthocorrection, Leica Photogrammetry Suite (LPS), thinning

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Background

Glaciers and alpine snowfields around the world are shrinking in response to Earth's warming climate (Dyurgerov and Meier 2000, 2005). Perennial snow and ice in the greater Yellowstone region are experiencing similar changes (Seifert and others 2009). Retreating alpine snowfields are resulting in the discovery of archeological and paleobiological materials (Dixon and others 2005, Hare and others 2004, Lee and others 2006, Müller and others 2003) in many locations, including the greater Yellowstone region (Lee 2007, 2008). While only a few locations harbor these resources, it is imperative that they be identified. Once the protective snow and ice melt, arrested decay processes resume, and fragile and irreplaceable artifacts quickly decompose. Thus, it is of great scientific and public interest to develop techniques to identify snow and ice fields that may contain archeological and paleobiological materials (figure 1). Estimating the historical minimum extent of these snowfields can act as a guide to prioritizing field inventories.

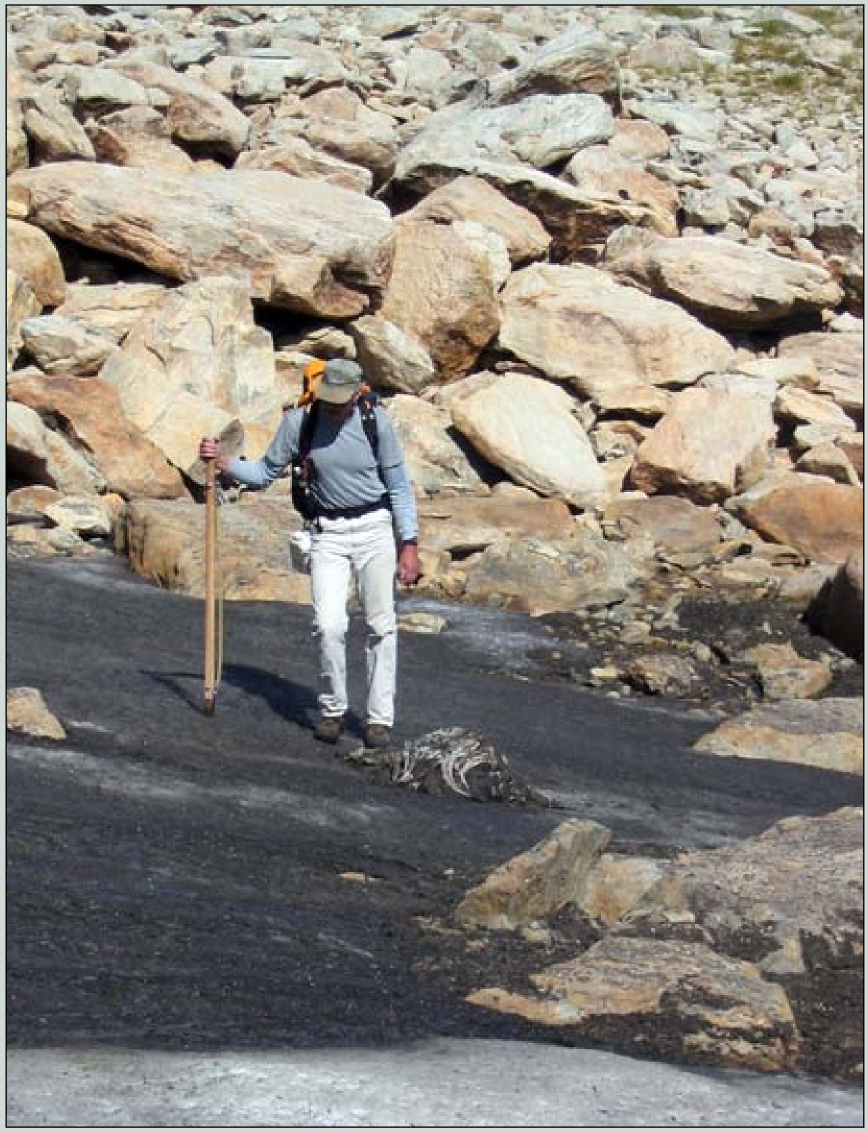

Figure 1—Archeologist Michael Bergstrom discovers a rooted tree stump at the base of an ice patch on Grass Mountain. The Engelman spruce specimen was determined to be approximately 8,000 years old using radiocarbon dating techniques.

In 2008, the U.S. Department of Agriculture (USDA), Forest Service, Remote Sensing Steering Committee awarded funding for a proposal submitted by the Custer National Forest to investigate methods to estimate the historical minimum extent of semipermanent alpine snowfields in the Absaroka-Beartooth Mountains (figure 2). Aerial photography provides the best historical record of these alpine snowfields, and the Forest Service has been systematically collecting resource aerial photography of all the land it manages since the 1940s and, in some areas, as far back as the 1930s. Typically, photo acquisition is repeated over a 5-to-10-year cycle.

Programs such as the National High Altitude Photography (NHAP) program, the National Aerial Photography Program (NAPP), and the current National Agricultural Imagery Program (NAIP) greatly supplement the available dates of resource photography. In addition, the U.S. Geological Survey (USGS) has a vast library of special-project photography for the study area.

A fortunate convergence of technology and available data now allows anyone in the Forest Service to use historical aerial photography to map and measure changes to alpine snowfields. The objective of this project was to develop a cost-effective procedure to monitor these changes and thus prioritize archeological and paleobiological inventories.

Methods

The project's general methodology consisted of 1) identifying alpine snowfields that are proven or likely candidates to contain archeological and/or paleobiological resources, 2) identifying and locating available photography, 3) scanning the photography, 4) orthocorrecting the photography, and 5) estimating the historical minimum extent of the alpine snowfields.

Identifying Suitable Alpine Snowfields

Two test sites in the Absaroka-Beartooth Mountains containing perennial snowfields where archeological and/or paleobiological materials had been identified were selected for the study[1].

Identifying and Locating Available Photography

The project used two sources of aerial photography: 1) original film from the Aerial Photography Field Office (APFO) and 2) existing print photography from the Custer National Forest, Beartooth Ranger District, acquired in 1932. The APFO has archived original film rolls for all USDA-contracted photo projects since 1955 (currently more than 50,000 rolls of film). The study selected five dates of photography within the APFO holdings for each site: 1951/52, 1971, early 1980s, early 1990s, and 2003. To facilitate selecting the correct photos, the aerial-photo flight-index map for each corresponding date was scanned, and each map was georeferenced and overlaid with the selected sites in ArcGIS. This allowed easy identification of the film rolls and exposure numbers that covered the sites.

Scanning the Photography

The resource photography obtained from the APFO was originally acquired at nominal scales of 1:15,840 to 1:24,000. All of these resource photos were scanned at 700 DPI on a desktop scanner. This resulted in nominal pixel sizes ranging from 0.6 to 0.9 meters and an uncompressed file size of about 120 megabytes for each photo.

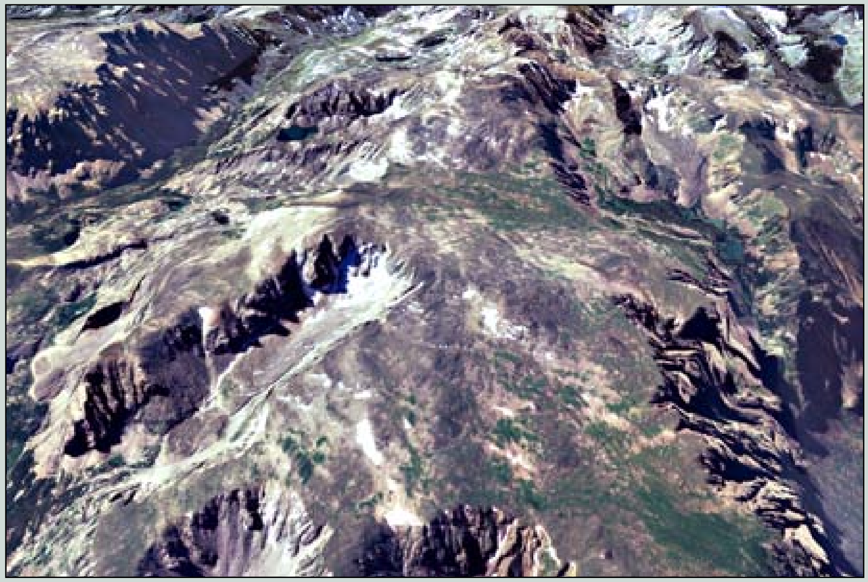

Figure 2—Typical terrain of the Beartooth Plateau. Only a few of the numerous perennial snowfields are likely to contain archeological and paleobiological materials. As these snowfields shrink, exposed materials quickly decompose. Thus, it is important to monitor snowfields of known archeological value to prioritize field visits.

Orthocorrecting the Photography

The photos were orthocorrected using Earth Resource Data Analysis System (ERDAS) Imagine's Leica Photogrammetry Suite (LPS), which requires digital elevation models (DEMs) and reference imagery that cover the specified area. LPS also requires camera reports for each date of photography. Camera reports were created for any dates that had none[2].

The photogrammetric orientation parameters for each set of photography (each date and each site) were defined with LPS. These definitions were saved in what LPS terms "block files." After the block files were fully defined, orthophoto mosaics of both sites were created for each date.

Estimating the Historical Minimum Extent

For each year of photography, the orthomosaic was inspected to see if it portrayed the minimum extent of any snowfields within the site boundaries. If it obviously did not, that date was discarded from subsequent analysis. (For example, 1971 was a big snow year, and much of the ground at both sites was snow covered at the time of photo acquisition; thus, the 1971 orthomosaic was omitted.) If the snowfield was not present on a particular date, that location was disregarded as a likely candidate to yield valuable materials. The boundaries were then digitized for those dates that potentially portrayed the minimum extent of the snowfield.

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[1] The selected sites had been identified by another Forest Service project sponsored by the Custer, Gallatin, and Shoshone National Forests and the University of Colorado's Institute of Arctic and Alpine Research (INSTAAR).

[2] The USGS Optical Sciences Lab periodically calibrates mapping cameras and publishes the results in a camera report. The report provides precise measurements (to 0.001 mm) of the characteristics of each camera system, including lens distortion, calibrated focal length, and fiducial measurements (fiducials are known locations on the film that become image control points in the orthocorrection process). Reports became a requirement for all mapping cameras in 1973 but are essentially nonexistent prior to that date.

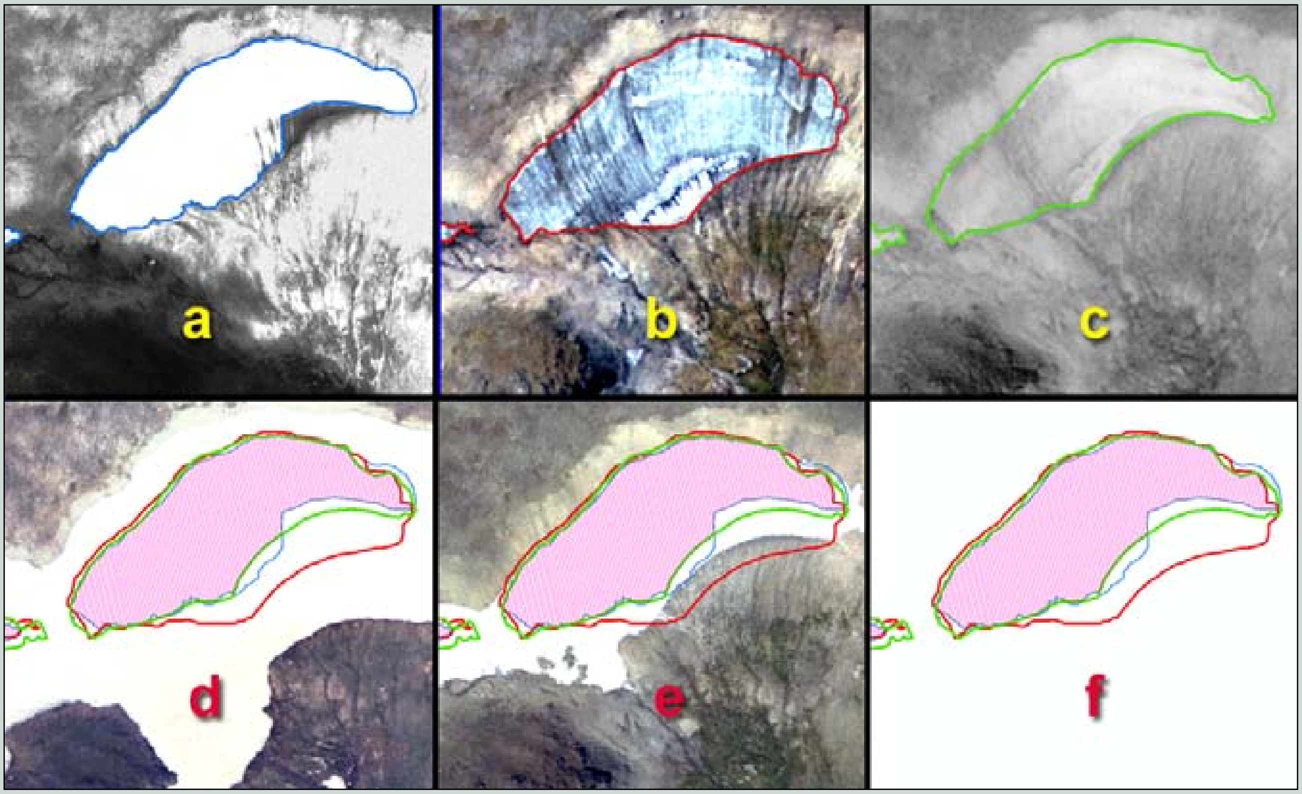

Figure 3—The historical aerial photography used for this analysis: *a)* 1932—the snowfield boundary digitized in blue; *b)* 1987—the snowfield boundary digitized in red; and *c)* 1994—the snowfield boundary digitized in green. Since the snowfield boundaries in 1971 *(d)* and 2003 *(e)* do not help identify the minimum snowfield extent, they were not digitized for those dates. The red cross-hatched area in *(d, e, and f)* represents the intersection of the 1932, 1987, and 1994 snowfield dimensions and thus the minimum extent of the snowfield according to the photo record.

After all of the dates of imagery were analyzed and digitized, the snowfield boundaries for all the dates were intersected to define the minimum extent of that snowfield according to the photo record (figure 3). Of course, the true minimum is probably less than the record indicates since it is unlikely that a photo would capture the year—much less the exact date—of least extent.

Results and Discussion

Identifying the minimum historical snowfield extent allows researchers to (1) eliminate areas from field inventory consideration where the snow has melted (since any artifacts or paleobiological materials have likely decomposed already) and (2) define a minimum snowmelt line that will expose new materials and can be verified visually through aerial reconnaissance—thus minimizing trips to the field when the snowfield boundary exceeds the historical minimum.

Costs

With several caveats, the approximate total cost to analyze one date of imagery at a typical alpine snowfield site is $560.00 (note: this type of analysis requires at least two dates of imagery). As already itemized, the tasks include identifying and locating available photography, scanning the photography or ordering scanned photography, orthocorrecting the photography, and analyzing the results of those measurements. There are several ways to accomplish many of these tasks, and costs can be quite variable. For simplicity, lets assume one alpine snowfield site for one date—requiring two photographs for complete coverage.

- Identifying and locating available photography (assumes access to flight-index maps)—3 hours
- Scanning the photography—2 hours
- Orthocorrecting the photography (including finding or making a camera report and downloading the DEMs and reference imagery)—5 hours
- Analyzing the data (includes evaluating and digitizing snowfield boundaries)—2 hours

Thus, the total labor time is approximately 10 hours ($50/hour x 10 hours = $500.00). This estimate (based on $50 an hour) assumes you have the required software, expertise, and familiarity with the procedures and that there are no unforeseen problems. The data are a relatively insignificant cost: 2 photos at $30 a photo = $60—producing a total cost of $560.00. This amount is then multiplied by the number of dates required for the analysis.

Conclusions

This project demonstrated a cost-effective method to monitor changes in perennial alpine snowfields using available technology and data—and to estimate the historical minimum extent of these snowfields. The test locations are known archeological and/or paleobiological sites. To date, the survey project identified in footnote 1 has noted a correlation between greater-than-average snowmelt years and more numerous artifact discoveries. This relationship can be evaluated further in upcoming years.

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