ELEVEN MILLENNIA OF HUMAN ADAPTATION IN COLORADO'S HIGH COUNTRY: MODELING CULTURAL AND CLIMATIC CHANGE IN THE SOUTHERN ROCKY MOUNTAINS

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Abstract

University of Northern Colorado researchers have conducted archaeological and paleoenvironmental field studies in Rocky Mountain National Park and the adjacent interior basin valley of North Park since 1998. Five hundred Native American archaeological sites, representing the full range of human habitation from the Late Pleistocene to Historic times, were recorded and many excavated. Nine lake, pond, and fen localities in environmental settings from sagebrush steppe to alpine tundra were sampled with manual and power coring, test excavations, and backhoe trenching. Collected sediment samples were analyzed for environmental and paleoclimate data and AMS radiocarbon-dated to provide chronology for paleoclimate and paleoecology reconstructions. Resulting paleoenvironmental data were correlated with Geographic Information System (GIS) maps of archaeological sites ranging from the Late Pleistocene (ca. 11,200 B.P.) to historic times (ca. 200 B.P.), forming the basis of a reconstruction of eleven millennia of human social and technological adaptations to environmental-ecological change in the Southern Rocky Mountains.

Researchers at the University of Northern Colorado (UNC) are synthesizing paleoclimate and archaeological data from more than a decade of research projects by the university and other investigators (cf. Brunswig 2003, Brunswig, Diggs, and Montgomery 2009; Brunswig et al. 2009, 2011; Diggs and Brunswig 2006, 2012; Doerner 2004; Doerner and Brunswig 2007, 2008, 2012; Elias 1983, 1985, 1988, 1991, 1996a, 1996b; Elias et al. 1986; Lux 2004, 2005; Quadracci 2004, Rohe 2003, 2004; Sullivan and Doerner 2002). The data are being entered into a compiled Geographic Information System (GIS) database and modeling project of Rocky Mountain National Park's prehistoric and early historic archeological and paleoclimate histories. Data park sets (e.g. those associated with soils, vegetation, geology, hydrology), locations of known cultural period archaeological sites, and recent ice patch evidence and data from the adjacent North Park mountain basin valley are being integrated into existing GIS project data layers. The final project goal is to simulate human land use patterns within the park's environmental zones from the end of the last Ice Age to early historic times.

Origins and Background to Project Research

University of Northern Colorado (UNC) researchers have conducted integrated and individualized interdisciplinary studies on Rocky Mountain National Park (RMNP) archaeology and long-term paleoclimate and paleoenvironment change since 1998. Initial research took place from 1998-2002 for the park's System-wide Archeological Inventory Program (SAIP). Although the SAIP project ended in 2002, subsequent research programs, including a leading-edge study of past Native American spiritual landscapes (Brunswig et al. 2009; Diggs and Brunswig 2006, 2013), have continued to the present. Since 1998 more than a thousand park sites were field recorded and entered into National Park Service and Colorado State Archaeological databases, including more than four hundred with prehistoric and historic Native American components. Hundreds of Native American hunting and plant processing camps, game drives, trails, and ritual sites were entered into Geographic Information System (GIS) databases and their relationships with park terrains, natural resources, and ecological zones modeled and mapped in time and space (Brunswig 2005b: 11-12; Brunswig et al. 2009; Brunswig, Diggs, and Montgomery 2009; Brunswig and Lux 2004; Butler 2004; Diggs and Brunswig 2006, 2013; Rohe 2003, 2004). All known human cultural periods from the earliest Clovis culture (ca. 11,200-10,900 B.P. [conventional, non-calibrated radiocarbon years before present] to removal of the park's most recent historic Native American (Ute, Arapaho, and Cheyenne) inhabitants (ca. 1870) have been documented within park boundaries (Brunswig 2003, 2005b, 2007, 2012).

Research Design and Data Sources

Corollary paleoclimate and paleoenvironment research, most in direct support of UNC archaeological studies, has been conducted by sediment coring, radiocarbon dating, and sediment trait analysis for paleoclimate and paleoecology proxy evidence (pollen, organic content, magnetic susceptibility, bulk density, etc.) at park locales ranging from montane valleys to subalpine and alpine ponds and fens. Our paleoclimate/paleoenvironment reconstruction program operates under a long-term research design submitted to RMNP in 2001 (Doerner and Brunswig 2012). That research design, which has since been revised, has provided a flexible and effective theoretical framework for a comprehensive sediment coring and paleoclimate/paleoenvironment research program. This framework has been applied to diverse park settings such as the lower elevation montane localities of Beaver Meadows (Doerner et al. 2001) and Bear Lake (Doerner 2008), as well as higher elevation upper montane, subalpine and alpine zones such as Lawn Lake (Brunswig 2001; Doerner et al. 2002), La Poudre Pass (Doerner 2005; Doerner and Brunswig 2007), Trail Ridge Game Drive Wetland and Mount Ida Ridge Fen

(Doerner and Brunswig 2008) and Forest Canyon Pass (Brunswig et al. 2009; Doerner 2009a). Sediment column chronologies from coring localities range from the Early Holocene to the Late Holocene. Basal maximum dates for UNC coring sites included La Poudre Pass, 9710 B.P., Milner Pass/Little Bighorn Fen, 7680 B.P., Lawn Lake Fen, 7330 B.P., Forest Canyon Pass Fen, 6520 B.P., Bear Lake, 6120 B.P., Mount Ida Fen, 5370 B.P., and Trail Ridge Game Drive Wetland, 2630 B.P.

A second source of archaeological and paleoclimate data comes from archaeological survey and excavation field studies in the large North Park basin valley immediately northwest of RMNP (Brunswig 2004b, 2005a; Brunswig and Sellet 2010, 2011; Doerner 2009b, 2010; Mayer 2008, 2009) (Figure 1). The North Park Cultural Landscapes Project research program complements RMNP research, providing collateral evidence of lower elevation (~2800 m.), interior mountain basin Native American occupations, and paleoclimate change dating to 9,000 B.P. or earlier.

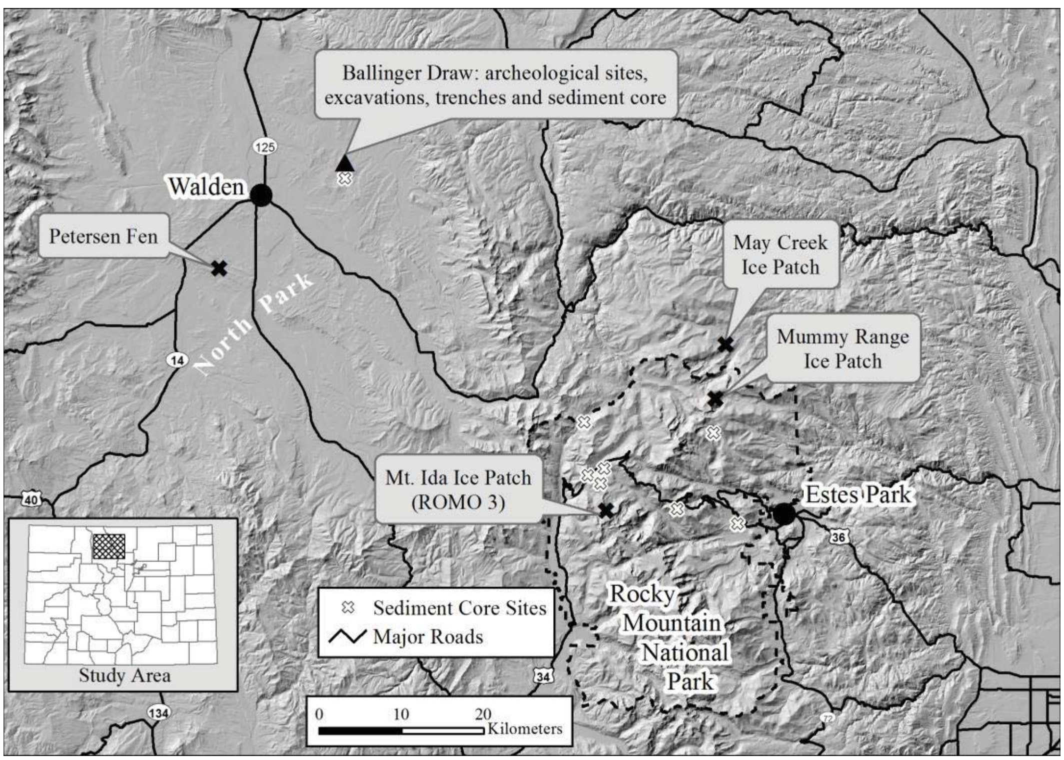

Figure 1. Map of RMNP and North Park showing paleoclimate research localities discussed in text.

Other important park and regional research data sources for reconstructing paleoclimate/paleoenvironment conditions occur in the form of organic materials and insect remains recovered from lake, bog, and fen deposits (Elias 1983, 1985, 1986, 1988, 1991, 1996a, 1996b, 2001; Elias et al. 1986; Short 1985; Reasoner and Jodry 1999), glacial geology (Benedict 1973, 1985; Outcalt and MacPhail 1965), and the study of ancient organic materials (tree and animal remains) buried in bogs, fens, melting glaciers and ice patches (Lee et al. 2006; Benedict et al. 2008; Lee 2011; Lee and Benedict 2012).

Eleven Millennia of Mountain Hunter-Gatherer Transhumance

After fifteen years of RMNP and North Park field research, there is abundant evidence that interior mountain seasonal hunter-gatherer transhumance was present as early as the Clovis period (11,200 B.P.) and became well-established by 9500 B.P (cf. Brunswig 2001, 2003, 2004a, 2004b, 2005b, 2007, 2012). The predominant transhumance pattern appears to have emphasized generally cool season (spring and fall winter) residence in interior montane valleys such as North Park, and warmer season (summer and early fall) migration to high elevation game foraging territories in subalpine and alpine environmental zones such as RMNP (see Figure 2 for RMNP prehistoric site locations in reference to park environmental zones).

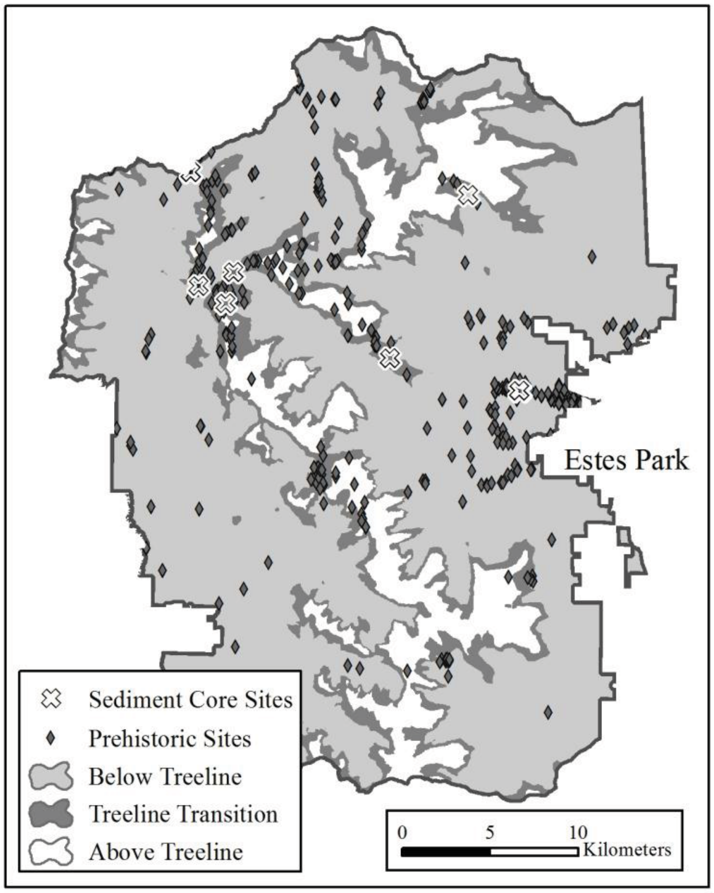

Figure 2. GIS map of RMNP showing the locations of UNC sediment coring sites, Native American archaeological sites, and modern environmental zones polygons with special emphasis on above treeline (alpine-tundra), treeline transition (alpine-subalpine ecotone), and below treeline (upper and lower montane) environmental zones.

Statistical frequencies of stone tool type and material source from RMNP's high altitude summer hunting camps show that 75-90% derived from local lower elevation montane valley sources (Brunswig 2005b: 176-187, 2007; Wunderlich and Brunswig 2004).

In one instance, discovery and chemical element analysis of obsidian artifacts at a North Park site led to identification of a tool-grade obsidian quarry source in RMNP itself— a source previously suspected but not formally identified and chemically analyzed in the earlier SAIP project (cf., Brunswig and Sellet 2010, 2011; Hughes 2006). Identification of the local source of tool obsidian reinforced evidence for seasonal transhumant migration between North Park and RMNP.

Earlier archaeological and/or paleoclimate histories syntheses in RMNP and its Southern Rocky Mountain region provide a firm foundation for the current project (Brunswig 2005b: 44-63; Doerner 2004, 2007), representing a substantial body of work on which to build a more advanced model for better understanding of cultural and climate/environmental change in RMNP and its region from the most recent glaciation to the present. Among anticipated project benefits are enhancement of our understanding of parameters and effects of climate and environmental change on natural and human landscapes in the past, and better assessment of the potential form and impact that global warming might entail in the near and distant future.

Project Components: Examples and Early Results

The RMNP GIS Mapping Project, planned for completion in 2013, incorporates four key components: 1) updating and integration of the park's 2005 SAIP and subsequent UNC-generated GIS data bases for spatial correlation and modeling of known archeological resources, natural resources, topographic, geologic, soils, hydraulic, and vegetation layers; 2) initiation of an *early phase* synthetic GIS mapping project of cultural and climate change over the past 11,000 years; 3) generation of added paleoclimate/paleoenvironmental records from glacial cirque ponds in the park's upper Forest Canyon Pass; and 4) exploration of a new subset of current GIS project data layers in the form of ice patch studies recently undertaken in the park.

Paleoclimate Evidence from High and Lower Altitude Lakes, Ponds, and Fens

Much of the project's paleoclimate data comes from six RMNP sediment core localities (bogs, fens, lakes, and ponds) and geological studies conducted in North Park Valley (see Figure 1 for locations). As noted above, RMNP coring sites located at, above, or just below modern treeline, such as La Poudre Pass, Milner Pass, Forest Canyon Pass, Mount Ida Ridge, and Trail Ridge Game Drive, and a new sediment coring site in the Forest Canyon glacial cirque valley scheduled to take place in summer 2012 provide a substantial set of records for paleoenvironment reconstruction.

Lower elevation (~2800 m.) interior montane paleoclimate research localities in North Park, while lacking the time depth of most RMNP coring sites, provide important comparative data on effects and parameters of regional paleoclimate patterns. For instance, four years of field research in a small interior spring-fed stream valley, Ballinger Draw, northeast of the mountain town of Walden, has provided detailed information of climate and geomorphic change extending well into the latest Pleistocene (Brunswig and Sellet 2010: 49-51, 2011: 9-30; Doerner 2009b, 2010; Mayer 2008, 2009).

Paleoenvironmental Methods

At our RMNP sampling sites, we extracted sediment cores from wetland sites using a square-rod piston sampler (2.5 cm diameter, 1 m sampler). The cores, recovered in segments, were wrapped in plastic film and aluminum foil and transported to the Paleoecology Laboratory at the University of Northern Colorado. In the laboratory, sediment samples were collected for radiocarbon dating and sediment analysis (loss on ignition, bulk density, and magnetic susceptibility). Bulk samples of sediment were submitted for accelerator mass spectrometry (AMS) radiocarbon dating. Continuous sub-samples of sediments were collected at 1-3 cm intervals for laboratory analysis (organic carbon content, bulk density, and magnetic susceptibility). Organic carbon content (loss on ignition, LOI) and bulk density (BD) measurements were determined using techniques modified from those described by Dean (1974). BD was calculated on oven-dried samples; LOI was determined using loss on ignition at 550^{o}C for two hours; MS was measured with a Bartington meter following standard techniques with a Bartington meter (Thompson and Oldfield 1986).

Proxy data (LOI, BD, and MS) obtained from sediments retrieved from lakes, fens, and other wetlands often provide sensitive, high-resolution records of environmental change. LOI is a measure of the build-up of organic matter which reflects biological productivity. When environmental conditions are more favorable (i.e. warmer or wetter) there is an increase in organic productivity (Andrews et al. 1975). Likewise when conditions are more limiting (i.e. colder or drier) there is a corresponding decrease in organic productivity. Variations in BD values reflect changing inputs of mineral material into a depositional location. Increases in bulk density coincide with periods of greater influx of fine-grained sediments by aeolian and/or fluvial processes. Typically paired measurements of LOI and BD are inversely related, because as one increases the other decreases. The MS curve tends to mirror the changes in the bulk density curve but it is more variable in its range.

Paleoenvironmental Interpretation

An example of the type of records we are compiling of past environmental change derived from wetlands is shown in a chart of plotted data from the Ballinger Draw 5AJ1808 profile (Figure 3) in North Park. The sediment curves (MS, BD, and LOI) show sensitivity to environmental changes through the peat section of the core. The profile illustrates a peak in MS at a depth of 100 cm. This peak is just below what appears to be significant cultural feature found at the site. Brunswig and Sellet (2010) identified multiple features (charcoal, fire-reddened sediments, and charred stones) associated with human disturbance that would account for this increase in MS.

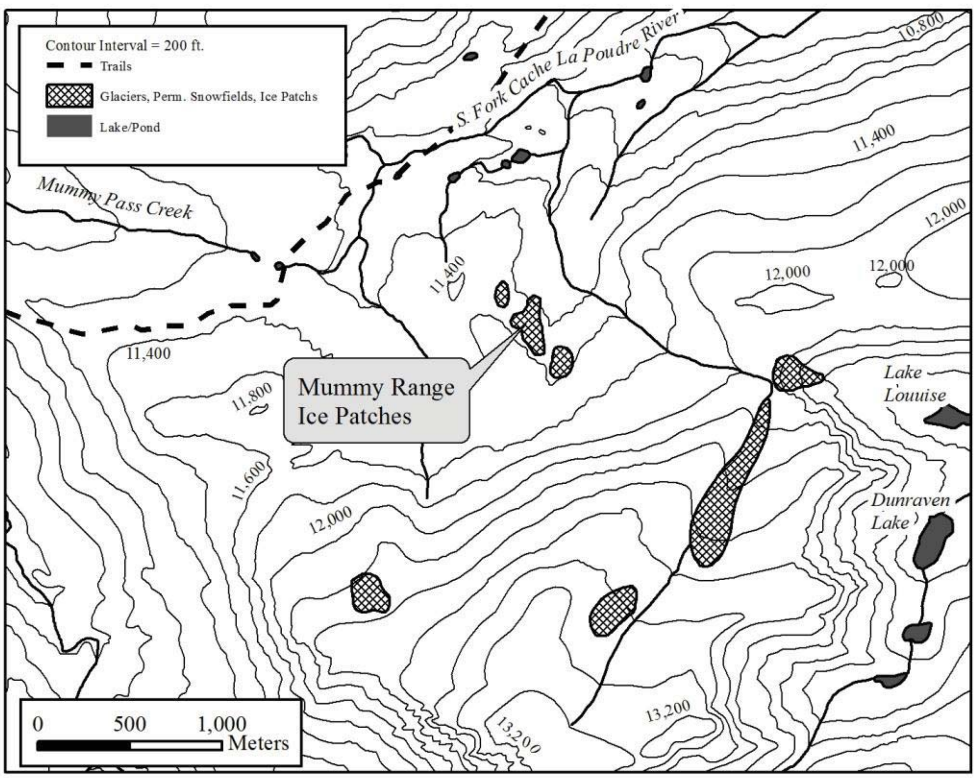

Figure 3. Stratigraphy, magnetic susceptibility (MS), bulk density (BD), organic carbon loss on ignition (LOI), and moisture proxy curves for the Ballinger Draw Fen (Profile 5JA1808). The moisture proxy curve is based on standardized z-scores (σ) derived from organic carbon loss on ignition (LOI) values, with positive σ values suggesting wetter conditions and negative σ suggesting drier conditions.

The organic carbon curve (LOI) provides a proxy record of paleoenvironmental change for the site. To better interpret the organic carbon signal (LOI, Figure 4), LOI data from the 5AJ1808 sampling profile were converted standard deviations (σ) from mean and plotted against time. If the standard deviation was positive it was interpreted as an increase in effective moisture (and/or cooler) where a negative standard deviation was interpreted as a decrease in effective moisture. Figure 4 clearly shows that from ca. 6300 to 4200 B.P., conditions at the site were likely considerable drier (and/or warmer). However, sometime after about ca. 4200 B.P., conditions changed and the site became more mesic as regional climate cooled. This cool period lasted until ca. 1000 B.P. when slightly drier (and/or warmer) conditions returned. This interpretation is consistent with the overall climate history from the nearby Front Range Mountains (Doerner 2007).

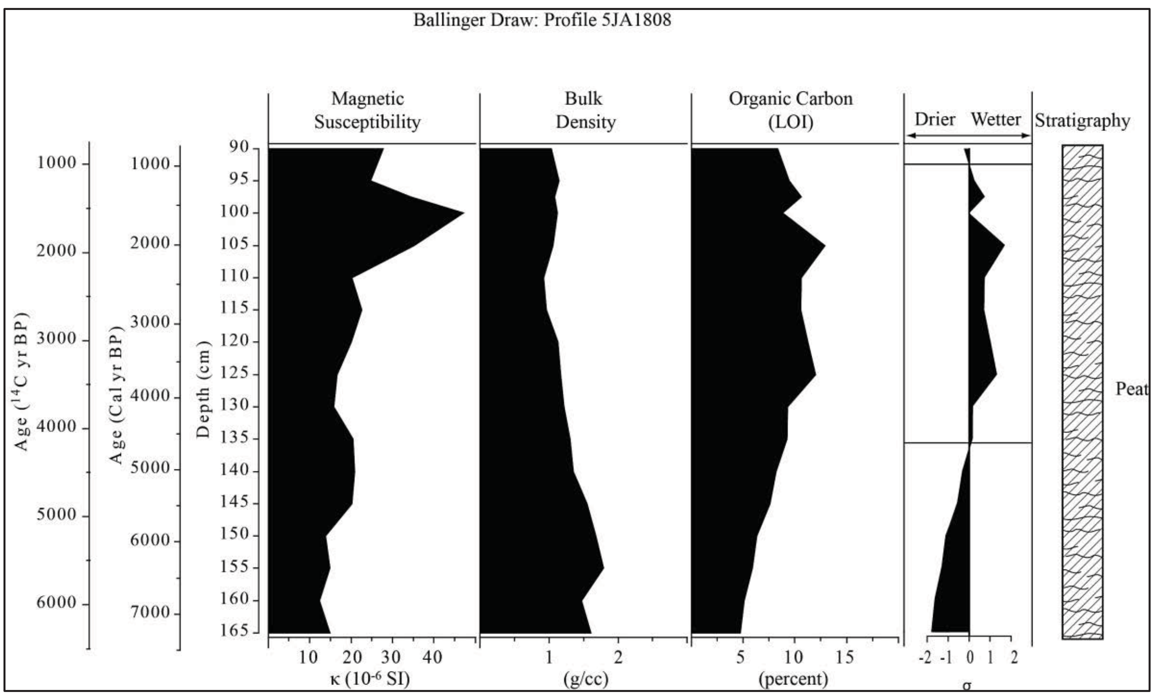

Figure 4. Temperature proxy curves for high elevation sites in Rocky Mountain National Park (La Poudre Pass, Lawn Lake, Forest Canyon, Mt. Ida, and Game Drive, 5LR15). The temperature proxy curve is based on standardized z-scores (σ) derived from organic carbon loss on ignition (LOI) values, with positive σ suggesting warm conditions and negative σ suggesting cool conditions.

For sites in RMNP (La Poudre Pass, Lawn Lake, Forest Canyon, Mt. Ida, and Game Drive, 4LR15), we also converted LOI values to standard deviations (Figure 4). Here we interpret a positive standard deviation score as indicating warmer conditions and negatives scores suggesting cooler temperatures. Because these sites are high elevation locations (at or above treeline, defined as “the upper altitudinal limit of symmetrical forest trees”, Benedict et al. 2008), we see temperature as the limiting factor, rather than moisture— as appears to have been the case for the lower elevation site in North Park (Ballinger Draw).

For comparison purposes the diagram was divided into four time periods based on visual inspection of the temperature curves (Figure 4) and important changes in the sediment characteristics: LOI, BD, and MS. The temperature proxy curves show moderate variability throughout the length of the cores. The early Holocene is identified as a cool period based on the La Poudre Pass record. That site also shows a period of warming followed by a brief cool period between ca. 8500 and 7000 B.P. The middle Holocene (ca. 7000 to 3000 B.P.) is characterized by warmer conditions and was therefore more favorable for accelerated build-up of organic matter (peat) in the Poudre Pass wetlands. Higher temperatures persisted until ca. 3000 B.P. when regional cooling occurred. The late Holocene is characterized by temperatures that were lower relative to the middle Holocene. These cooler conditions persisted until about ca. 1000 B.P. Climate during the early portion of the most recent millennium is characterized by rising temperatures associated with the medieval climate anomaly (MCA, approximately 950–1250 CE; Mann et al. 2009).

Our data suggest that temperatures cooled slightly after the MCA and the cooling may be associated with the Little Ice Age. However, insufficient chronological control in the upper portion of the RMNP cores precluded assigning definitive dates within this period. Our preliminary findings are consistent with results from previous paleoenvironmental studies from the Northern Front Range and will be further refined as project data analysis continues and a new RMNP coring site in Forest Canyon, noted earlier, is sampled and analyzed in summer 2012. However, the findings described here illustrate methodologies and approaches we are taking in modeling paleoclimate change in our project.

Mapping Ancient Treelines through Time: Fens, Bogs, and Ice Patches

In part, the project explores GIS-based reconstruction of extrapolated spatial distributions of environmental zones through time vis-à-vis the locations of high-altitude summer hunting camps, base camps, and game drives of known cultural period archaeological sites. These spatial distributions are studied in relation to shifts in treeline and warm season accessibility of alpine tundra to migratory game and the humans who hunted them. Both treeline and tundra summer accessibility are determined by longer-term climatic episodes which promoted conditions ranging from extended summer growing seasons to severely reduced growing seasons and expansion of upper elevation, permanent snowfields, ice patches, and glaciers.

Our effort to simulate historic changes in treeline along the alpine-subalpine boundary, or ecotone, relies on GIS mapping of modern treeline contours as a comparative baseline. This has been accomplished by creation of a GIS layer from the current RMNP GIS vegetation database and cross-checking it with a 1m resolution, geo-spatially referenced National Agriculture Imagery Program (NAIP) aerial photo layer (cf. Mathews and Davis 2007; U.S. Department of Agriculture 2008) (illustrated by Figure 2 above).

Although their abundance is limited at present, an important source of data on paleoclimate and environmental (paleoecology) change and treeline shift patterns in the Southern Rocky Mountains are upper montane tree remains recovered from bogs and ice patches. South of Rocky Mountain National Park, James Benedict recovered a spruce (*Picea engelmanni*) log from Caribou Lake bog in 1971 (1973, 1985). The log, AMS radiocarbon dated at 9200±135 B.P., was recovered at an elevation of 3400 m at upper margins of the local alpine-subalpine treeline. Basal peat recovered from the same bog, below a glacial cirque pond, was found to contain spruce needles dated even earlier at 9915±165 B.P. In his report, Benedict concluded that treeline and Early Holocene climatic conditions at the time were equivalent to the present. That assessment was supported by discovery of spruce cones and wood fragments from another bog in the same cirque valley, also on the alpine-subalpine treeline boundary and dated at 9720±220 B.P. and 9520±160 B.P.

Another source of important paleoclimate data and an indicator of prehistoric treelines in recent years is from ice patch research. Ice patch studies are based on the fact that compacted snow melted and refroze in mountain hollows and protected slopes, forming long-lasting ice and compacted snow concentrations which resisted melting, often for thousands of years. The most significant fact of ice patches is not that they are rapidly disappearing due to global warming, but that they sometimes contain fossil trees preserved in their icy matrix—trees that provide clues to the location of ancient treelines and past climate.
Ice patch data has recently become available in and near RMNP through research conducted by Craig Lee (2011, *personal communications*) of the University of Colorado's Institute of Arctic and Alpine Institute Research (INSTAAR) and the

late James Benedict of the Mountain Archeology Center Benedict and Lee (2012) at park sites and the May Creek locality north of the park on the Arapaho-Roosevelt National Forest (locations shown in Figure 1). Lee and Benedict have been the primary ice patch researchers in the Colorado Rockies (Benedict et al, 2008; Lee 2011; Lee and Benedict 2012).

It is a testament to global warming that ice patches, which have survived so long, are now melting away with North America's disappearing glaciers. Lee and Benedict's surveys in RMNP in the late 2000s identified four ice patches above present-day treeline with exposed logs and wood fragments (Lee 2011; Lee and Benedict 2012). Two, Mummy Range Ice Patch C and ROMO 6, produced spruce (*Picea engelmanni*) wood submitted for AMS radiocarbon-dating (Lee and Benedict 2012: Table 2). Four Mummy Range Ice Patch logs produced outer ring dates between 3860 and 3780 B.P. Averaged ring counts of the logs provided an estimated age at death of 286 years, suggesting they began growing at the site no later than 4066 B.P. Mummy Range Ice Path C is located at 3475 m, approximately 43 meters above the local modern treeline. Figure 1 shows the location of the Mummy Range and ROMO 3 ice patches. A detailed map of the local Mummy Pass Ice Patch C is shown in Figure 5).

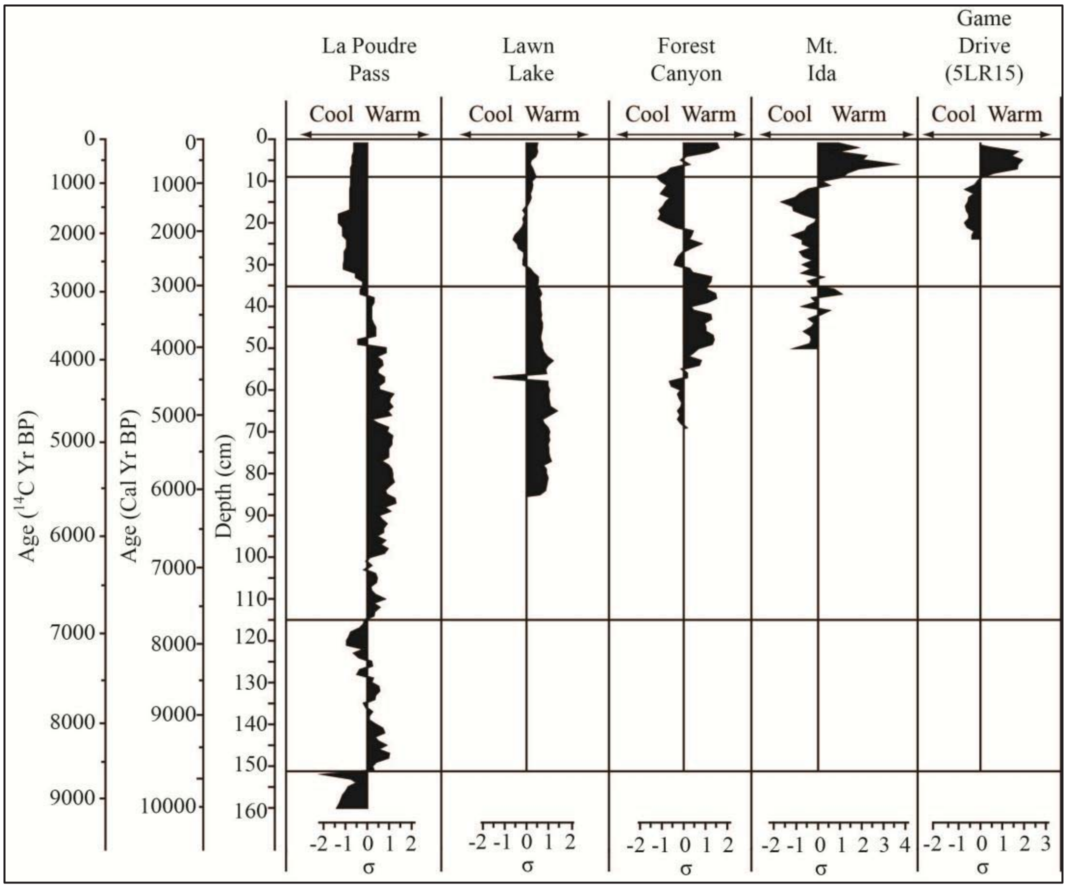

Figure 5. Contour map of the of the Mummy Pass Ice Patches, AMS dated at ca. 3900 B.P., showing their relationship to local topography, streams and lakes. Note the protective northwest facing nature of the ice patch locations which helped preserve them through 4000 years of cyclical climate, including multiple warm intervals.

The ROMO 3 Ice Patch is located in the western central area of RMNP on alpine tundra immediately west of the continental divide (Figure 1). Similar to Mummy Range Ice Patch C, it produced spruce (*Picea englemanni*) wood melting from the ice. The wood was AMS radiocarbon-dated at 3855±15 B.P., an identical age to the Mummy Range samples. The ice patch, at 3487 m, is approximately 70 m higher in elevation than the local alpine-subalpine treeline.

Nearly thirty years ago, Scott Elias recovered a sediment core at an alpine pond north of the park's Mount Ida at an elevation of ~3450 m, 30-40 m above local treeline. The pond is located a short distance from the above described Lee and

Benedict ROMO 3 ice patch. Elias interpreted results of pollen and fossil insect analyses of the pond's core sediments as supporting local existence of higher than present-day alpine-subalpine treeline between 9000 and 8300 B.P. (Elias 1985: 33, 35-36, 43-45). He also recovered conifer needles and salix wood fragments in sediment core layers between upper and lower layers radiocarbon-dated between 9070 and 8340 B.P.

Conclusions

A fourteen-year sustained program of archaeological and paleoenvironmental research in RMNP and the adjacent sedimentary basin valley of North Park has provided an unparalleled Southern Rocky Mountain database for reconstructing cultural and paleoclimate/paleoenvironmental change from the latest Pleistocene to modern times. Combined with the power of Geographical Information System (GIS) software and today's computers, it is now possible to realistically model adaptive responses of eleven millennia of Native American hunter-gatherers to fluctuations in climate and the effect of that change on mountain ecosystems so essential to their survival and success. Just as importantly, knowledge of those same patterns of climatic and environmental change will allow modern humans to plan for and anticipate some of what the future, affected by increasingly apparent global climate change, may have to offer future generations.

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