THE CONTEXT OF CULTURE CHANGE:
ENVIRONMENT, POPULATION, AND PREHISTORY IN EASTERN COLORADO,
1000 B.C. – A.D. 1540

A Dissertation
Presented to
the Faculty of Natural Sciences and Mathematics
University of Denver

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
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June 2008
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ABSTRACT

This dissertation research examines the interplay between prehistoric population dynamics and paleoenvironment, and the extent to which these factors influenced culture change over the last 3000 years on the western High Plains of Colorado. The population dynamics of prehistoric hunter-gatherers in eastern Colorado were estimated using several proxies, including the summed probability distribution of radiocarbon ages from archaeological sites in eastern Colorado. Understanding paleoenvironments of the western High Plains is critical to understanding prehistoric human adaptations to past climates and to predicting the magnitude and consequences of current climate change in this semi-arid region. Analyses of sediment cores from small fens (groundwater fed peatlands) on the High Plains indicate they contain high resolution (sub-decadal) paleoenvironmental records that extend into the middle Holocene (ca. 7800 BP). These “pocket fens” are small peatlands (25-2500 m²) sustained by springs fed by perched water tables. Fluctuations in the relative humification and organic content of peat from these features provide proxies for effective moisture and temperature, respectively. Due to the heterogeneity of the sediments contained within pocket fens, new methods of data analysis and display have been developed to compensate for sediment differences within and between fens. Data from pocket fens suggest that they contain sensitive records of relatively low magnitude climate fluctuations.
Well-dated, high-resolution records of paleoenvironment are important because they allow a more detailed examination of the complex relationship between climate, population and culture change. Here, these records from pocket fens not only document extended periods of high amplitude deviations in climate (such as drought) that could have influenced cultural adaptations, they also document periods of high temporal variability in proxy temperature and effective moisture that could have disrupted existing cultural systems. Periods of high temporal variability in climate would result in lower predictability of environment-dependent resources on an annual and decadal temporal scale, which in turn might have exceeded the inherent resiliency of cultural adaptations available within the knowledge base of these systems. Episodes of drought and high temporal variability in conjunction with periods of increasing population pressure correlate to periods of culture change during the past 3000 years in the archaeological record for eastern Colorado. This suggests that increased population and climate variability drove prehistoric culture change.
ACKNOWLEDGMENTS

I would like to first and foremost thank my dissertation committee Don Sullivan, Paul Sutton, Matthew Taylor, Doug Bamforth and my outside chair Larry Conyers. This dissertation is the product of discussions with these fine scholars and was much improved by their (not always gentle) ministrations. Pocket fens would have remained an obscure and possibly completely unknown source of paleoenvironmental data without the encouragement of my advisor Don Sullivan, who has proven to be a patient mentor, an engaged colleague and excellent friend throughout this process. I would also like to thank Mike Castellon for teaching me a greater appreciation of culture. My father, John B. Gilmore provided support (financial, emotional, and practical) for my academic endeavors, including financing AMS dates, providing field support, processing sediment samples in the lab and extending debt forgiveness; for all of these things and more he has my gratitude and love.

I would like to thank the land owners who allowed me to trample their tiny wetlands: Max Canestorp of the U.S. Fish and Wildlife Service at the Pueblo Chemical Depot; Duke Phillips and the staff at Chico Basin Ranch; Mrs. Mildred Dyson of Flagler and Sean McEniry of American Quality Landscape. Fellow graduate students Kyle Schlacter and Heidi Guy-Hayes have earned my thanks for assisting me in the field and in the lab, and special thanks to Kyle for continuing to help long after he wasn’t depending on me to give him a good grade. Thanks also to Odie Bliss of the Colorado Climate Center at Colorado State University for providing historic climate records for the Denver and Pueblo areas.
Max Canestorp and the Pueblo Chemical Depot provided funding to support this research, as did the Colorado Archaeological Society, Alice B. Hamilton Scholarship Fund, the University of Denver, Department of Geography, Jerry Kulcarcien Graduate Research Fund, American Water Resources Association-Colorado Division, Rich Herbert Memorial Scholarship, and the University of Denver Professional Research Opportunities for Faculty Grant to Donald G. Sullivan. I appreciate the help provided by Alex Leonard at the National Science Foundation Arizona AMS Facility, and Dr. A.J. Timothy Jule and Dr. Greg Hodgens for allowing me to participate in the student outreach program which provided 22 AMS dates for my research. Thanks to Mark Chenault and family for providing all of the comforts of home during my stay in Tucson while I was working at the AMS facility.

Finally, I thank my wife Pam, daughter Sam and mother Shirley for their love and support and (almost) limitless patience during this long process. Now we all can heave a sigh of relief.
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CHAPTER 1

INTRODUCTION

“Past peoples were neither ignorant bad managers who deserved to be exterminated or dispossessed, nor all-knowing conscientious environmentalists who solved problems that we can’t solve today. They were people like us, facing problems broadly similar to those that we now face. They were prone either to succeed or to fail, depending on circumstances similar to those making us prone to succeed or to fail today. Yes, there are differences between the situation we face today and that faced by past peoples, but there are still enough similarities for us to be able to learn from the past.”

Jared Diamond, Collapse 2005:10

This dissertation research examines the interplay between prehistoric population dynamics and paleoenvironment, and to what extent these factors influenced culture change over the last 3000 years on the western High Plains of Colorado. The population dynamics of prehistoric hunter-gatherers in eastern Colorado were estimated using several proxies, including the summed probability distribution of radiocarbon ages from archaeological sites in eastern Colorado. The paleoenvironment of the High Plains is reconstructed in the multi-proxy records derived from the sediments of “pocket fens,” small wetlands that have proven to contain at least decadal resolution sedimentary records of paleoenvironment extending into the middle Holocene. Well-dated, high-resolution records of paleoenvironment are important because they allow a more detailed
examination of the complex relationship between climate, population and culture change. These records from pocket fens not only document extended periods of high amplitude deviations in climate (such as drought) that could have influenced cultural adaptations, they also document periods of high temporal variability in proxy temperature and effective moisture that could have disrupted existing cultural systems. Periods of high temporal variability in climate would result in lower predictability of environment-dependant resources on an annual and decadal temporal scale, which in turn may have exceeded the inherent resiliency of cultural adaptations available within the knowledge base of these systems. Episodes of drought and high temporal variability are both coincident with periods of culture change in the archaeological record for eastern Colorado.

Although the archaeological record of eastern Colorado documents cultures that were far from static, this research focuses on two periods of particularly rapid culture change. The first is the transition between the Late Archaic and Early Ceramic periods seen ca. AD 100-200 in eastern Colorado. This transition is characterized by many of the technological, economic and social innovations that are almost universally associated with the shift between Archaic and Formative cultural patterns. The second is the transition between Early Ceramic/Developmental period (ca. AD 100-1100) and the Middle Ceramic/Diversification period (ca. AD 1100-1540). This latter period was characterized in the Platte and upper Kansas River Basins of northeast Colorado by increased mobility and population dispersal and in the Arkansas River Basin of southeast Colorado by increased sedentism and population aggregation initially, followed by dispersion and out migration. This research uses the cultural data contained in the
prehistoric contexts for the Platte River Basin, which includes the upper Kansas River Basin (Gilmore et al. 1999) and the Arkansas River Basin (Zier and Kalasz 1999). The paleoenvironmental data are taken from analysis of sediment cores from pocket fens in eastern Colorado (Gilmore 2006; Gilmore and Sullivan 2006; Gilmore and Sullivan 2007).

**Identification of the Problem**

The relationship between climate change, prehistoric population and culture change is a topic that is of great interest to archaeologists, geographers and environmental scientists, and the relationship between these variables is complex. Culture change has often accompanied climate change, and, although cultural systems are dynamic and adaptive, there are also many examples of prehistoric population decline, dispersion and/or migration that coincide with drought and increased climate variability. This suggests that, in some circumstances, changes in culture in response to changes in climate are insufficient to maintain in situ population levels. Although I do not argue for a deterministic relationship between population and environment, it is arguable that climate change can provide the impetus for many changes seen in the archaeological record, including changes in population size, density and distribution, and changes in cultural adaptations (Brenner et al. 2001; Gill 2000; Jones et al. 1999; Weiss and Bradley 2001).

As well as being influenced by climate, population increase also has its own momentum, and modeling the introduction of new species (including humans) into a previously unoccupied territory suggests that population grows exponentially; it is initially slow, with more rapid growth occurring once the landscape contains sufficient
population density to provide the optimal combination of available territory and mate availability (Fix 2002; South and Kenward 2001). Ultimately, population growth is constrained by resource availability or carrying capacity is increased through cultural innovation (Cohen 1995; Malthus 1791). This ability of human groups to respond to increasing population through the development or adoption of cultural innovations and intensification to increase carrying capacity can be overwhelmed by environmental change that outstrips the available technologies (Tainter 2006). In order to meaningfully address the effect of population dynamics and climate on culture in prehistory, proxies for population and paleoclimate need to be developed. The sedimentary records from “pocket fens” meet the need for a source of continuous records of paleoclimate on the plains, and the methods for deriving these records are described below. This leaves perhaps the more difficult task of developing population proxies for hunter-gatherers. The following section outlines a method that has explanatory value.

**Estimating the Population of Hunter-Gatherers in Eastern Colorado**

Estimates of prehistoric hunter-gatherer population are rarely attempted for several reasons. Unlike populations of sedentary people for whom momentary population estimates can be made based on the floor-areas of contemporaneous habitations and dated to a narrow time period using ceramic chronologies, hunter-gatherer groups are often highly mobile, and their impact on the landscape is ephemeral. The consequent meagerness of the archaeological record of these people coupled with the less precise chronologies derived from radiocarbon ages renders momentary estimates of their population difficult by standard methods. The few attempts that have been made to
measure the population of prehistoric hunter-gatherers have met with mixed results. Measures of prehistoric human population based on environmental factors, such as carrying capacity derived from estimates of the biomass for a given environment, are a useful starting point (i.e. Hassan 1981). However, these models only provide a measure of the potential population of a given environment, and make assumptions about both cultural adaptations and resource use that are almost always difficult if not impossible based on archaeological data, and also assume that environment and culture are static. These mathematical methods strive to derive precise population number for a given region and usually result in a predicted range of population so large as to be of little practical use, or a specific figure that is impossibly precise (see Upham 1992). Yet even if the derivation of actual population numbers is beyond current methodologies, I believe that proportional changes in prehistoric hunter-gatherer populations can be determined by several methods.

The number of archaeological components cross-dated to a particular cultural-historical period has been used widely as a rough measure of relative size of population, and the frequency of radiocarbon dates through time has also been used as a more detailed indicator of the relative size of population or intensity of occupation in large areas (Chatters 1995; Gilmore et. al. 1999, Prentiss et al. 2005; Reed and Metcalf 1999, Zier and Kalasz 1999). I recognize that issues of site formation, differential preservation of landforms and research bias in a particular geographic area could potentially skew these data. However, the large size of the regions investigated here and the resulting wide variety of depositional contexts (fluvial, eolian and colluvial) within mountain, foothills and plains environments represented, coupled with the large number of sites recorded
during cultural resource management projects (which document all of the sites within a specific project area) militate against these biases. Even taking all of these issues into consideration, archaeologists recognize that the number of components recorded for a certain period of time in a large area does in some way reflect the number of people who lived in an area at that time. Based on this measure, archaeologists have hypothesized an increase in population in eastern Colorado between the Late Archaic period (ca.1000 B.C.-A.D. 150) and the Early Ceramic period (ca. A.D. 150-1150) in the Platte Basin and the Developmental period (ca. A.D. 100-1050) in the Arkansas Basin. This increase in population culminates at the end of the Early Ceramic period in the Platte Basin, but continues through the Developmental period and into the Diversification period (A.D. 1050-1450) in the Arkansas Basin. However, since the length of different cultural periods varies widely, the number of components cross-dated to a given period is not directly comparable to the number for any other period unless these counts are normalized using the amount of time covered by each period, using the Index of Occupational Intensity (IOI; number of components in a period divided by the length of the period multiplied by 1000) (Larmore and Gilmore 2006). As I demonstrate in Chapter 3, graphing the IOI by period within the prehistoric cultural chronologies of the Platte and Arkansas River Basins of eastern Colorado supports what archaeologists have suspected, that the number of components increases through time and peaks in the Early Ceramic period in the Platte Basin and in the Diversification Period in the Arkansas basin. This result is somewhat at odds with the distribution of uncorrected radiocarbon dates for the Arkansas Basin, which indicates a peak in population toward the end of the Developmental period.
These different lines of information suggest an increase in population after the Late Archaic period in both basins, and a subsequent drop in population after the Early Ceramic period in the Platte Basin and the Diversification period in the Arkansas Basin. However, due to the length of cultural periods, the level of resolution of IOI data is so low that it has limited utility in determining the nature and structure of this hypothesized increase and decrease, and the distribution of uncorrected radiocarbon dates seems at odds with the component data, showing a drop in proxy population in the Developmental Period rather than in the Diversification period.

Using the summed probability distribution of calibrated radiocarbon dates as a proxy for population dynamics has an advantage over these methods. Although not a representation of actual population numbers, the summed probability distribution associated with the set of calibrated radiocarbon dates from archaeological sites in the Platte and Arkansas basins presented in Chapter 3 does provide a visual representation of the rise and fall of population and/or occupational intensity; the higher the peaks in the curve, the higher the probability contributed by radiocarbon ages from dated features created by prehistoric people. The resulting aggregated probability curves serve as a high-resolution proxy for relative size and concentration of prehistoric population for a given area. However, the nature of the calibration curve suggests that some caution should be exercised with this method. As a result of fluctuating concentrations of atmospheric $^{14}C$ through time, the calibration curve is not a straight line, but a series of peaks and valleys that document these fluctuations. As a result, some of the lower amplitude peaks and valleys on the population proxy curve are artifacts of the calibration and not a reflection of population dynamics. For example, “wiggle matching” (Ramsey et
al. 2001; Mauquoy et al. 2004) the summed probability curves to the radiocarbon calibration curve makes obvious some of these artifacts. This is especially obvious in the summed probability curve for the Arkansas Basin after A.D. 1300 (and to a lesser extent the curve of the Platte Basin for the same time period), which reflects the calibration curve rather closely. There are also several flat sections of the calibration curve that are reflected in the summed probability distribution curves for both basins. However, the larger trends do not reflect the calibration curve and these higher amplitude changes are the ones that document population. Gamble et al. (2005) and Shennan and Edinborough (2007) all point out that these curves are remarkably stable, and maintain the same general shape even when curves are generated from large random samples of radiocarbon dates from a particular region.

Calibration of radiocarbon ages and the generation of summed probability distribution curves for this study was accomplished using the shareware program CALIB version 5.0 (Stuiver and Reimer 1993; Stuiver et. al. 1998). Summed probability distribution curves generated from radiocarbon dates have been used elsewhere as proxy measures of the relative size of prehistoric populations, but the focus of most of these studies were relatively small geographic areas such as a portion of the Southern Rocky Mountains in Colorado (Benedict 1999), the so called “Vacant Quarter” of the lower Ohio River Valley (Cobb and Butler 2002) and the southern coast of British Columbia (Lepofsky et al. 2005). The studies of larger regions have to date focused on late Pleistocene to middle Holocene populations in Europe (Gamble et al. 2005; Shennan and Edinborough 2007). All of these studies stress the relative nature of this method as an indicator of population trends, and not representing actual numbers.
Focusing on the last 3000 years in the Platte and Arkansas basins, the summed probability curves of calibrated radiocarbon curves for both areas suggest that some changes in population were in phase during this period, while some changes were out of phase. These data reflect the same patterns observed above, but deliver it at a level of resolution that allows for a more detailed examination of the record. An increase in summed probability at the transition between the Late Archaic and the Early Ceramic/Developmental periods ca. A.D. 1-200 suggests that population increase may have contributed to the adoption of the technological innovations and social restructuring (adoption of the bow and ceramics, among others) that characterize the Archaic/Formative transition in Colorado. After approximately 800 years of population increase, proxy population peaks in the Platte Basin ca. A.D. 1000-1150. This comes at the end of the Early Ceramic period, which is characterized in the archaeological record by increased sedentism, larger group size and limited evidence of incipient corn horticulture. A relatively precipitous decrease in population follows this peak into the Middle Ceramic period (A.D. 1150-1540), which is characterized in the archaeological record by evidence of smaller more ephemeral sites indicative of a more dispersed and mobile population (Brunswig 1996; Gilmore 1999). Proxy population peaks somewhat later in the Arkansas Basin (ca. A.D. 1200-1300) in the middle of the Diversification Period (A.D. 1050-1450). This period is characterized by a general trend toward increased sedentism and more substantial and clustered habitation structures, limited corn agriculture and aggregation of Apishapa phase populations in larger village sites (some of which were fortified) (Kalasz et al. 1999). The current research proposes to examine how population dynamics in the Platte and Arkansas basins effect culture change in each area,
and to examine how the patterns in proxy population and archaeological data suggest interaction between the Platte and Arkansas basins.

Along with population, climate change has been demonstrated to influence culture. Archaeologists have long posited the influence of climate on culture change in eastern Colorado and the Great Plains in general (Brunswig 1996; Wedel 1986; Tate and Gilmore 1999). However, due to the lack of records of paleoclimate specific to the plains, records from the periphery have been used to extrapolate into the heart of the plains. The records from pocket fens provide continuous records of paleoclimate that are far superior to other sediment records available for the High Plains, these records exceed the temporal depth of tree-ring records available for the plains and pocket fens are apparently far more common than other sources for continuous records.

**Paleoclimate Proxies from Pocket Fens**

As mentioned above, the sediment records recovered from pocket fens distributed throughout the western High Plains can supply the sort of high-resolution paleoenvironmental data necessary to examine prehistoric population and adaptation in detail. A multi-proxy approach allows for data not only to be cross-checked, but multiple lines of evidence for changes in temperature and effective moisture, and the response of vegetation communities to these changes, allow for a more valid and nuanced interpretation of past conditions.

The research proposed here will continue investigation of the records of paleoenvironment contained within the sediments from “pocket fens,” which are small (25-2500 m³), inconspicuous features on the landscape. Partly because of their small
size, they are subject to high rates of sedimentation (0.04-0.5 cm/yr), which provides decadal to sub-decadal resolution paleoenvironmental records. The pocket fens so far investigated have contained 135-400 cm of peat and organic sediment, which have provided continuous records of effective moisture and relative temperature that extend to the middle Holocene (ca. 6000 B.C.). The discovery of pocket fens as sources of paleoenvironmental information overcomes several obstacles to examining long term climate change on the western High Plains, such as the general lack of paleoenvironmental data sources specific to the plains, and the inherent limitations of those that are available.

Paleoenvironmental records previously available for the plains include tree ring records, which are sources of very high-resolution (annual scale) continuous records of paleoenvironment. However, records within the margins of the plains are extremely limited in their spatial distribution and temporal depth (Cook et al. 2004; Cook et al. 1999; H. Weakly 1962; W. Weakly 1971; Woodhouse et al. 2002). Fluvial and eolian sediment records can yield valuable information on past conditions, especially episodes of drought (Daniels and Knox 2005; Forman et al. 2001; Madole 1995, Mason et al. 2004), but due to the discontinuous nature of depositional processes and loss of portions of the record due to erosion, these proxies rarely reflect a complete record of past conditions. Recent studies using data from low elevation lakes on the Northern Plains (i.e. Fritz et al 1993, 2000; Laird et al. 1996) demonstrate that these features preserve continuous records of climate change. Unfortunately, perennial lakes do not exist on the semi-arid High Plains, and so continuous sediment records were thought to be unavailable for this area prior to the investigation of pocket fens.
In contrast to other sedimentological sources for paleoenvironmental proxies, all classes of mires such as bogs (ombrotrophic, or precipitation fed peatlands), fens (minerotrophic, or groundwater fed peatlands) and marshes (fens with grass cover over a mineral versus organic substrate) provide an environment in which sediments accumulate continuously over time (Charman 2002; Chambers and Charman 2004). The physical, chemical and biotic characteristics of these sediments reflect the environmental conditions under which they were deposited, thus providing a proxy record of local and possibly regional environment over thousands and in some cases over ten thousand of years. Until now, most research has focused on records of paleoclimate derived from the sediments of bogs found in northern latitudes (Blackford and Chambers 1991, 1993; Langdon and Barber 2004, 2005; Roos-Baraclough et al. 2004) or high elevation in western Colorado (Sullivan and Gilmore 2005; Sullivan, Taylor and Williams 2004; Taylor 2003, Williams 2005). Like larger peatlands, analysis of sediments from pocket fens suggests they also contain high quality archives of paleoenvironmental data (Gilmore 2006; Gilmore and Sullivan 2006; Sullivan and Gilmore 2005, 2006a, 2006b).

Obviously, the investigation and understanding of the lower elevation paleoenvironments of the plains and their response to changing climate would be greatly enhanced with data that were collected directly from low elevation sources. To this end, sediment cores were obtained from several small fens in eastern Colorado. Cores were collected at the U.S. Army Pueblo Chemical Depot (PCD) and the Chico Basin Ranch localities in the Arkansas River Basin, the Dyson Ranch locality in the headwaters of the South Fork of the Republican River, and the Pawnee Buttes and East Colfax Avenue localities in the South Platte River Basin.