THESIS

COOKING WITH ROCK:
AN INVESTIGATION OF PREHISTORIC HEARTH MORPHOLOGY IN NORTHERN COLORADO

Submitted by

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ABSTRACT

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Hearths are a focal point for the organization of prehistoric hunter-gatherer activities, and can reveal a wealth of information regarding subsistence, settlement, chronology, and technology. However, despite the direct association with human behavior and the breadth of information these features offer the archaeologist, hearth morphology and the distribution of different feature types through time and space has largely been ignored. With this in mind, this research will address three main questions: are there temporal and spatial patterns to hearth morphology; are there spatial and temporal patterns in the material recovered from hearth features; and do changes in hearth morphology through time coincide with documented changes in paleoclimate, and other systemic changes in prehistoric culture? This study is focused on Boulder, Grand, Jackson, Larimer, and Weld counties of northern Colorado, and utilizes 190 radiocarbon dated hearth features, representing 72 individual archaeological sites. The features used in this study range in age from Paleoindian to Protohistoric, and are distributed across plains, foothills, montane, and subalpine/alpine environments. Collectively, this research seeks to better understand specific adaptive changes in past human culture, their causes and correlations, and how these changes in prehistoric culture are manifest in the distribution and morphology of hearth features in northern Colorado.

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for helping me track down some of the site and feature data used in this study, and Dan Bach for providing me with invaluable analysis and advice on all things macrobotanical.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION AND STATEMENT OF OBJECTIVES

Few archaeological features are as ubiquitous and immediately indicative of past human use of landscapes as hearths. Representing a focal point for the organization of space, not to mention a critical resource for any activities taking place after sunset, the broad occurrence of these features in the archaeological record is no surprise. What is surprising, however, is that despite the direct association with human behavior, their visibility on the landscape and the breadth of information these features offer the archaeologist including direct and indirect evidence of subsistence and temporal affiliation, few investigations have been directed at understanding formal variation in feature design. One need only take a cursory look through the literature, or a passing glance at a northern Colorado prehistoric campsite to realize the diversity in hearth construction techniques, which vary widely in terms of design, utilized materials, and size.

Defining Questions

With this in mind, the research will address three main questions, and in doing so, provide some insights on a hitherto largely unexplored topic. Specifically, this research project is structured around three seemingly simple questions: are there temporal and spatial patterns to hearth morphology; are there spatial and temporal patterns in the material recovered from hearth features; and, do changes in hearth morphology through time coincide with documented changes in paleoclimate, and other systemic changes in prehistoric culture? Collectively, these research questions seek to better understand specific adaptive changes in past human culture and their causes and correlations. Temporally, this study includes thermal features from all periods of northern Colorado regional prehistory, but due to the nature of the sample (and particularly the destructive effects of time) this work will largely focus on the Archaic and Late Prehistoric periods of Great Plains and Rocky Mountain prehistory. In the interest of establishing specific boundaries (in terms of space and workload), the research is entirely focused on Larimer, Weld, Boulder, Jackson, and Grand counties of Northern Colorado. A county approach does not entirely do justice to the dynamics of past human culture, but rather is a function of modern archaeological resource management data that is structured at the county level.

Basis for Study

Interest in formal thermal feature variation is not entirely unheard of; some authors have taken a similar interest in the apparent variability of hearth morphology. Stiger (2001: 102-110) noted the temporal patterning of distinctive hearth types in the Upper Gunnison Basin of Colorado as well as changes in the size of some features over time. He argues that these differences reflect efforts to create distinctly different burning conditions, an argument made elsewhere (Dering 1999; Smith and McNees 1999; Thoms 2008a; Thoms 2008b; Thoms 2009; Wandsnider 1997) that reflects the diverse way in which these features were integrated into other activities on a given site. Similarly, Joyner (1983) found hearth features to exhibit spatial and temporal patterning in the Hanna Basin of southern Wyoming. Her research also suggests a correlation between changes in morphology, artifact assemblage composition, and environmental conditions.

Several archaeologists have directed scholarly inquiry towards the function of specific morphological types, particularly slab-lined cylindrical basins (Smith and McNees 1999) and earth-ovens (Dering 1999; Smith, Martin, and Johansen 2001; Wandsnider 1997). However, woefully little research has been oriented towards establishing a systematic typology for hearth construction that would allow for meaningful comparison between these studies and, more importantly, a problem-solving methodology for identifying the causal factors that drive morphological variation.

Amongst the limited research aimed at understanding formal thermal feature variation, Thoms (2009) argues that elaborations in hearth design and the use of cook stones specifically indicate increasing labor investment in cooking techniques directed at utilizing a greater proportion of a given landscapes food-resource potential. He argues that as more plants are utilized in the diet, more rock is utilized in feature design (Figure 1-1), and points to global demographic expansion as an explanation for the proliferation of 'hot rock cooking' throughout the Holocene. Wandsnider's influential article on food composition and processing (1997) illustrates the relationship between cooking strategies and the complex carbohydrate content (particularly inulin and fructan) of many plant food-resources, a point also made by Smith and McNees (2005) and Dering (1999). Accordingly, I propose that there are patterns to the spatial and temporal distribution of different hearth feature types in northern Colorado, and those changes in hearth morphology reflect adaptive changes in subsistence strategies and indicate a shift beginning in the Archaic period towards a more diverse diet and an increased reliance on lower-order plant food resources; such resources require intensive processing in order to make them digestible and to increase their nutritional value (Wandsnider 1997). Furthermore, I argue that these subsistence adaptations are the result of changes in landscape use strategies, itself, in turn, as a function of climate change. Of interest is the variable effect of the middle Holocene (Altithermal) climate beginning between 8000 and 7500 radiocarbon years before present (RCYBP) and the amelioration of middle Holocene drought conditions after ca. 4000 – 5000 RCYBP (Antevs 1955; Meltzer 1991; Meltzer and Collins 1987). This study employs both uncorrected (RCYBP), as well as corrected dates (cal BP – see Chapter 4). Site and feature discussions utilize the uncorrected dates for clarity and archival purposes. Additionally, general trends in paleoclimatic and cultural data are often addressed in uncorrected RCYBP, as broad, published date ranges are not suitable for calibration. Individual, specific dates can be calibrated and their associated probability distributions summed to produce calibrated ranges; the specific patterns in thermal feature morphology are discussed in terms of calibrated, summed probabilities where appropriate (Chapter 6). At the theoretical level, this study is based on optimum foraging theory and more specifically, the dietary breadth hypothesis.

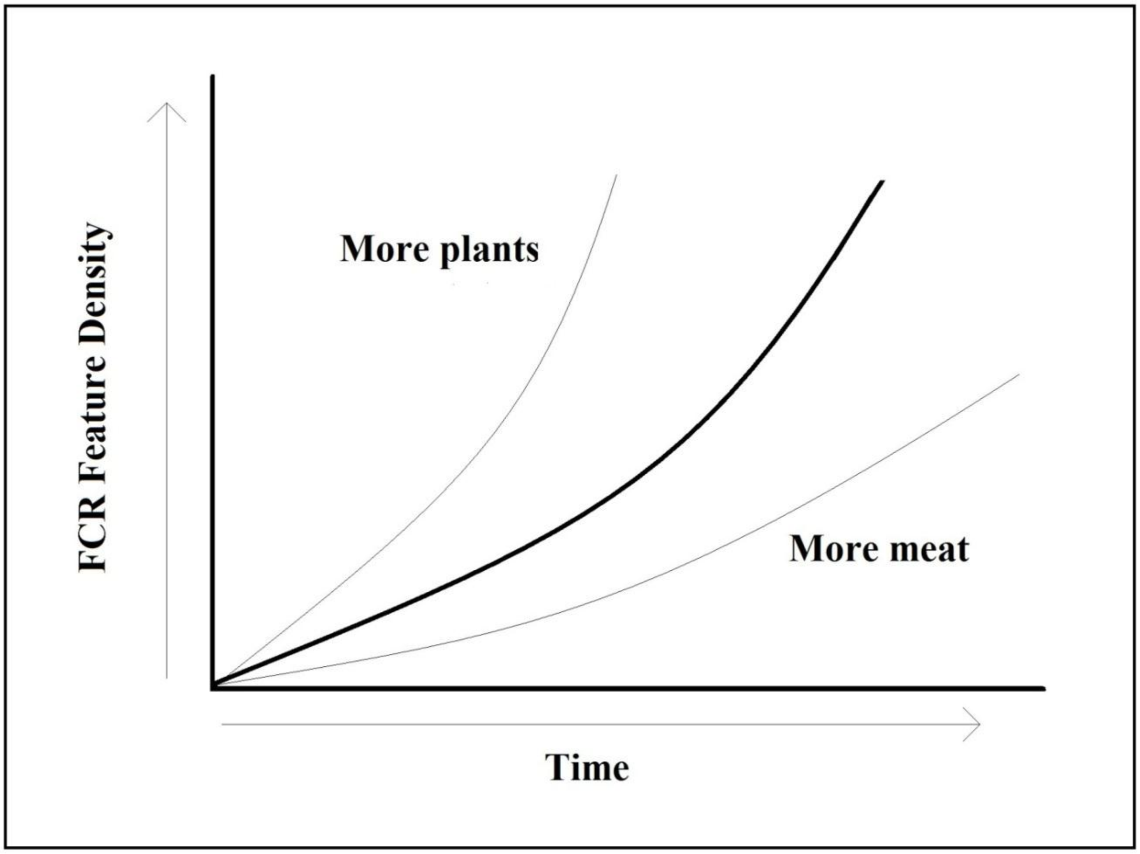

Figure 1-1: Model of FCR feature use-intensity, adapted from Thoms 2009

Optimal foraging theory, in its most basic form, argues that foragers will adopt strategies to maximize the *net rate of return* (in terms of caloric energy, nutrients or some other currency) while minimizing the *costs*, that is, the time and energy expended procuring and processing food resources (Bettinger 1987; Bettinger 2009; Smith 1983; Smith and Winterhalder 1985; Winterhalder 1980; Winterhalder 1983; Winterhalder 1986; Winterhalder 2001; Winterhalder and Kennett 2009; Winterhalder and Smith 2000). Specifically, optimal foraging theory argues that behaviors that maximize inputs while minimizing outputs improve individual *fitness* within a given set of environmental constraints. In turn, increases in fitness promote the likelihood of passing those specific behaviors on, and subsequently increasing their representation through time (discussions of the mechanism of behavioral transmission, that is genetic evolution and cultural learning, are often deliberately avoided and beyond the scope of this work, though in my opinion, irrelevant, as both are equally viable – see Chapter 8). This theoretical approach is useful for understanding the organizational principles of subsistence-mobility practices as it assumes that humans exploit resources in patterned, often (but not always) optimal ways. This study is not, however, a formal test of optimization theory – we simply do not have, at this time, the breadth and depth of data necessary for a formal test of the optimization model. Rather, this study employs the general principles of the theory.

Returning to the topic of hearths once again, I argue then that changes in feature morphology coevolve with the increasing use of lower-order plant foods in an effort to extract a greater amount of the food-resource potential from a given landscape as human subsistence-mobility strategies adapt to middle Holocene climatic conditions.

Specific Aims

To address this hypothesis, I have organized the thesis around three specific aims:

1. The development of a database of hearth morphology organized by time and space
2. The development of a macrobotanical and fuel wood database for the various hearth morphological types, and
3. Assessment of predictions regarding resource use derived from morphological, macrobotanical, and fuel wood data against existing paleoclimatological models for the northern Colorado prehistoric past.

I first address the lack of standardization in hearth description by developing a classificatory scheme that is broad enough to include the diversity of known feature types and yet is sensitive enough to detect subtle changes over time and space. In addition, I give considerable attention to changes based on elevation, as changes in climatic conditions are differentially experienced at different altitudes. This model was developed by synthesizing available data on hearth morphology (radiocarbon-dated features) from the Colorado State Historic Preservation Office files, cultural resource management (CRM) records, existing literature, published thesis and dissertation work and unpublished data and reports available through the Center for Mountain and Plains Archaeology (formerly the Laboratory of Public Archaeology). Additionally, I supplement this literature review with my own and others work in and around the Soapstone Prairie and Red Mountain open spaces in northern Larimer County, Colorado, as part of the Colorado State University archaeological field school, under the direction of Dr. Jason M. LaBelle. At the largest scale, the research focuses on Larimer, Jackson, Weld, Boulder, and Grand counties. This sampling strategy accounts for a wide array of altitudinal and ecological zones, spanning the Colorado Piedmont and foothills in the east, over the northern Front Range and through the North and Middle Park valleys.

The second aim of the project is to build a macrobotanical and fuel wood database for the various hearth types. This is addressed through the synthesis of the complied data mentioned above and detailed in Chapter 7. At the small scale however, this was achieved through systematic sampling, flotation, and analysis of hearth feature contents excavated by CSU in northern Larimer County, Colorado. Initial documentation includes profile illustrations detailing the location of recovered charcoal for dating and identification as well as the location of excavated soil samples. The amount of soil excavated depended on the size of the hearth and the context. A minimum of 2 liters is generally necessary for analysis. In the event a hearth feature is under some immediate threat of destruction, full excavation may be, and in many cases was, the preferred option. Flotation of recovered samples was conducted by the author and those under the author’s direction at the Center for Mountain and Plains Archaeology laboratory using a flotation device based on the design used by Dan Bach of High Plains Macrobotanical Services in Cheyenne, Wyoming. The effectiveness of this flotation system has been demonstrated in over ten experimental trials. Once floated, the samples were sent to High Plains Macrobotanical Services for analysis.

The third aim of the project is to assess predictions regarding past subsistence strategies derived from patterns in hearth morphology and content, against existing data of prehistoric subsistence and paleoclimate for the area in question. The morphological and macrobotanical data generated from this research, and existing techno-subsistence, and paleoclimate data will be synthesized to address the question of landscape use; specifically, how use of the foothills and mountainous regions changed throughout the Archaic and Late Prehistoric periods, and how that is reflected in hearth morphology. In other words, how did subsistence-settlement strategies change with the onset of the Altithermal and how did subsequent groups adapt as middle Holocene conditions wore on?

CHAPTER 2 REGIONAL PHYSIOGRAPHY AND PALEOENVIRONMENT

The following chapter discusses the physiographic setting and paleoenvironmental data for the study area. The purpose of this chapter is to better orient the reader to the level of diversity within the study area and how that diversity structures subsequent investigations of hearth morphology through space and time.

Northern Colorado Physiographic Setting

North-central Colorado comprises a large amount of altitudinal, ecological, and physiographic diversity. The spatial boundary of the present study encompasses the short-grass steppe to the east, the central foothills, montane, and alpine zones, and the intermountain basins to the west. In terms of elevation, the research area includes altitudes of just over 1,400 m (4,500 feet) in eastern Weld County to over 4,000 m (14,259 feet at Longs Peak). Collectively, the area encompasses over 9000 feet of elevation change and all the associated floral and faunal diversity that comes with it (Armstrong et al. 2010; Weber and Wittmann 1992). The following describes the major physiographic provinces and altitudinal regions located within the study area.

In the eastern part of the study area, the expanses of short-grass steppe stretch across the western interior of the Great Plains. The grassland continues across the Colorado Piedmont, a broad, erosional depression resulting from shifts in the North American Plate, and associated increases in river runoff and erosion along the eastern slopes of the Rocky Mountains (Epis and Chapin 1975). The Colorado Piedmont itself stretches from the intersection with the High Plains, along the Colorado-Wyoming border, south to the Palmer Divide. As the piedmont intercepts the foothills of the Southern Rocky mountains, it creates a right angle between the north-south trending foothills uplift, and the east west trending bluff formation resulting from the down cutting of the Cache la Poudre and South Platte River drainages through the deposits of the High Plains.

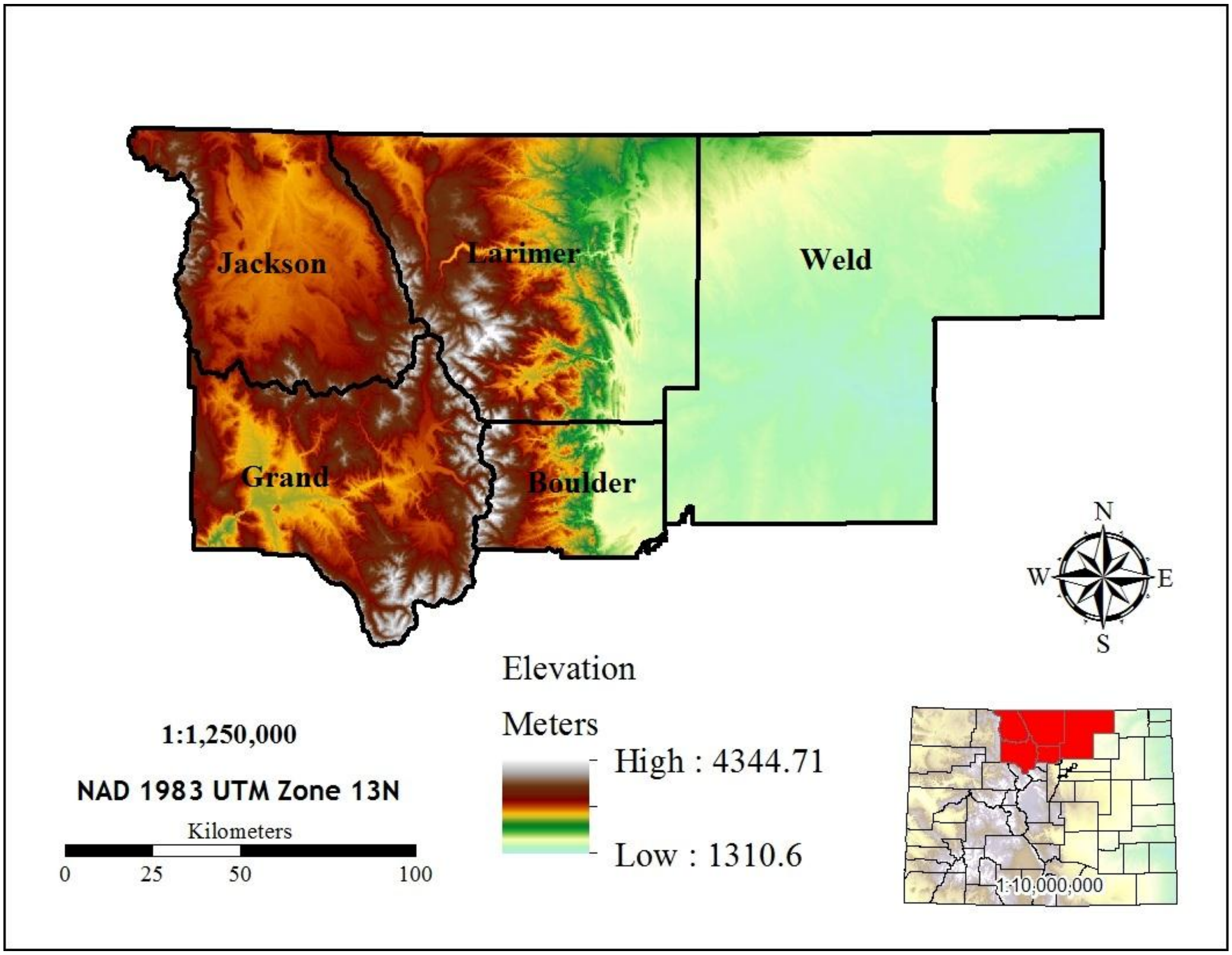

Figure 2-1: Northern Colorado topography and the counties used in this study

The Southern Rocky Mountain foothills of northern Colorado begin in the western half of Larimer County and in central Boulder County. Rising from an elevation often below 1500 meters, the foothills are the narrow band of intermediary elevation uplifts and low-relief valleys immediately east of the Rocky Mountains. In the northern part of Colorado, the foothills are only a few miles wide, readily giving way to the northern Front Range, and southern Laramie and Medicine Bow Mountains. The foothills ecotone is widely diverse, representing the contact between the High Plains grassland, and the coniferous, montane forests. The biotic and physiographic transition between biomes is often dramatic across northern Colorado, given the relative narrowness of the transitional foothills ecotone. Accordingly, the area is home to a wide variety of plant and animal species, and is frequented, at various times throughout the year, by species that are more migratory. Noteworthy among these are the large ungulates, principally deer, elk, pronghorn, and in the past, bison, as they were often the principle targets of prehistoric hunter-gatherers. There is also clear evidence of exploitation of some of the smaller, permanent foothills residents, including coyote, fox, rabbits, rodents, and various bird species (Kornfeld et al. 2010: 291-342). Moreover, there is growing evidence (this work included) that suggests the diversity of plants within this environment was equally if not more attractive to past peoples.

Figure 2-2: Montane topography, Rocky Mountain National Park, Larimer County

Figure 2-3: Foothills topography, Red Mountain Open Space, Larimer County

Figure 2-4: Plains topography, Weld County

As elevation increases, moving to the west, the foothills rise to meet the Southern Rocky Mountains. Gradually, the mixed grass/shrubland and piñon/juniper forests (though often without much piñon in northern Colorado, except for the Owl Canyon Piñon Grove [Betancourt et al 1991]) give way to aspen and evergreens, including Colorado blue spruce, white fir, as well as lodgepole, ponderosa, and bristlecone pine. The Southern Rocky Mountains are home to a wide variety of animals including deer, elk, moose, mountain sheep, bobcat, lynx, mountain lion, black bear, and numerous rodent, bird, and reptile species.

Broadly speaking, the counties of interior northern Colorado are delineated by and along the major mountain ranges. Accordingly, a discussion of the boundaries of the study area is, in reality, a discussion of mountain ranges. The Southern Rocky Mountains of interest, within north-central Colorado are a series of north-south trending ranges, and comprise the Park Range, Rabbit Ears Range, Gore Range, Mummy Range, Indian Peaks, Never Summer Mountains, Medicine Bow Mountains, and Laramie Mountains. Beginning again, in the east, and progressing clockwise, the Medicine Bow Mountains form the border between western Larimer County and eastern Jackson County. Just to the south, in western Boulder County and eastern Grand County, the mountains of the northern Front Range, including the Mummy Range, Indian Peaks, and Never Summer Mountains separate Middle Park from the Colorado Piedmont and plains. To the west, the Gore Range and Park Range delineate the western border of the study area. The Rabbit Ears Range and part of the Never Summer Mountains create the east-west trending uplift that stretches between the Northern Front Range and Southern Park and Gore Ranges, and collectively, separates North Park, drained by the North Platte River, and Middle Park, drained by the Colorado River.

This high elevation part of the study area comprises the headwaters of three major river drainages, the Colorado, the North Platte, and the Cache la Poudre Rivers. The importance of the Colorado River to the American Southwest cannot be overstated. With its headwaters just south of La Poudre Pass in Rocky Mountain National Park, the Colorado River flows south and west, through Middle Park, across the Colorado Plateau, through Utah and Arizona, turns abruptly south, forming part of the border between Arizona and Nevada, and the entire border between California and Arizona.

The Cache la Poudre River forms in the northern part of Rocky Mountain National Park. The headwaters are just north of La Poudre Pass, and just across the continental divide from the headwaters of the Colorado River. From la Poudre pass, the river flows north a few miles, and then meanders east through the mountains and foothills, descending over 2000 meters, and emerges to the northwest of Fort Collins. From there the river flows east to its end at the confluence with the South Platte River, which in turn flows northeast to the confluence with the North Platte.

The headwaters of the North Platte River comprise nearly all of Jackson County. The river drains the North Park basin, which is delineated along the western slopes of the Medicine Bow Mountains, the northern rim of the Never Summer and Rabbit Ears Ranges, and the eastern slope of the Park Range. The river flows north out of Colorado, east through central Wyoming and into Nebraska, where it meets the South Platte River and forms the Platte River. Collectively, the three provide a substantial amount of irrigation water to the central interior Great Plains.

Rivers and mountains fundamentally shaped the prehistoric human presence on the landscape. Specifically, rivers follow the fundamental principle of the path of least resistance. Accordingly, rivers define travel corridors across the flat, semi-arid, and largely featureless eastern plains, as well as through, and nearly over the foothills and mountains. Indeed, modern Colorado transportation corridors through the Rocky Mountains frequently parallel the major rivers: Interstate 70 and the Colorado River, State Highway 14 and the Cache la Poudre River, US Highway 50 and the Arkansas and Gunnison Rivers, and U.S. Highway 34 and the Big Thompson River, just to name a few. Predictable streams and rivers provide landmarks across the landscape that makes transportation through the mountains easier and more cost effective. In the past, the same rivers were the lifeline of mobile hunter-gatherers and made transportation through these environments possible, and predictable.

Much in the same way rivers provide structured transportation routes through the plains and into the mountains, the low elevation passes between mountains create structured and predictable routes through them. Moreover, many of the more popular mountain passes utilized by modern transportation networks were similarly frequented throughout the past (Gooding 1981). The fact that seasonally mobile animal species, such as elk, mountain sheep, and, in the past, mountain bison, similarly utilize these areas certainly added to the appeal. In fact, many of the mountain passes of northern Colorado testify to extensive past human utilization via the presence of elaborate animal control features and hunting structures (Benedict 1996, Gooding 1981).

The diversity of the interior counties of northern Colorado is as attractive now as it was thousands of years ago. It is not surprising that the river corridors, confluences, and mountain passes that we frequent and inhabit today represent some of the most densely occupied and utilized areas in the past. The study area delineated herein allows for a meaningful, manageable, and regionally discrete analysis of the role of altitudinal and associated ecological diversity and the effect it may (or may not have) on past human use of the landscape and adaptive subsistence changes through time.

Regional Paleoenvironment

Space is not the only variable presently under consideration. The current research project tracks adaptive changes in subsistence and material culture across space, but importantly, also through time. Understandably, the prehistoric environment of the western Great Plains and Rocky Mountains was not static over the period of interest, that is, since the arrival of humans. Though the inferential nature of archaeological interpretation renders conclusions subject to dispute, much of the available evidence indicates that humans arrived in North America (and hence, progressively, the study area) sometime during the Late Pleistocene (ca. 13000 years BP; Chenault 1999). Accordingly, a thorough discussion of prehistoric North Americans and variable environmental settings within which they lived and operated necessarily begins at the end of the last ice age.

The environmental context of the Terminal Pleistocene/ Early Holocene transition is one characterized by change. The period represents the end of the Pleistocene glaciation (late glacial) and the beginning of the trend towards more or less modern conditions (postglacial). The terminal Pleistocene landscape consisted of large expanses of grasslands covering much of central and western North America. A wide range of megafauna, the absolute population of which was probably low due to high seasonal mortality and inter and intra-species competition, populated the landscape in configurations that lack a modern analogue (Hill et al. 2008). Ecologically, the Great Plains most closely resembled the modern arctic steppe: a patchy, mosaic habitat characterized by non –arboreal taxa consistent with cooler and drier, seasonally equable conditions (Kay 1998). The transition to warmer post-glacial conditions began sometime shortly after 14,000 RCYBP and was only briefly interrupted by the Younger Dryas around 11,000 RCYBP (Doerner 2007). As the climate changed, (either gradually or in dramatic, punctuated shifts) the late glacial boreal forests retreated, leaving in their wake a series of successional ecological changes. Notably among these, the large expanses of mixed, diverse, late glacial vegetation (largely C_3 plants) were replaced by more homogeneous, drought tolerant, and less nutritious C_4 plants. Collectively, these changes served to increase competition between and within species and led to dramatic population crashes, particularly among large herbivores and predators that relied directly upon them, and in many examples resulted in extinction.

Immediately following the Late glacial, is the postglacial, a period of regional history characterized by the retreat of the Laurentide ice sheet in northern North America, and generally drier and warmer conditions. Reasoner and Jodry (2000) analyzed pollen concentrations from high altitude lacustrine sediment cores from two localities in the northern Colorado Front Range to infer changes in vegetation associated with the Younger Dryas climatic oscillation. The Younger Dryas event is a brief cooling period, contrasting with the general warming pattern following glacial retreat in North America, and dated around 10900 – 10000 RCYBP. The authors compare arboreal and non-arboreal taxa frequencies from radiocarbon dated lacustrine sequences to a regression equations developed from the relationship between elevation and selected pollen ratios in modern surface samples from the Colorado Front Range. Their analysis suggests a near-synchronous response in pollen accumulation rates and ratios of arboreal to non-arboreal taxa associated with both the beginning and termination of the Younger Dryas event. The data indicate a downslope movement of tree line roughly 60-120 meters during the Younger Dryas interval and a re-advance shortly thereafter. This point is supported by Benedict (1985), who demonstrated the generally drier and warmer conditions across the Southern Rocky Mountains around 9800 RCYBP by pointing to the colonization of alpine areas above 3350 meters by spruce trees.

The story of the Middle Holocene is in many ways the story of the Altithermal. First identified by Antevs (1955), the Altithermal was a period of generally drier and warmer conditions than present, the peak of which is largely contemporaneous with the early Plains Archaic period: 8000- 5000 RCYBP. The Altithermal was a drought of variable effect that had an impact throughout western North America. There appears to have been a general north-south trending gradient of precipitation, with the Southern Plains receiving very little moisture compared to the Northern Plains of Montana and Saskatchewan.

However, there appears to be a great deal of regional variability in the effect and magnitude of the Altithermal and, it follows that local-level climatic conditions were equal, if not greater determinants in past human subsistence and settlement strategies. Additionally, Benedict and Olson (1978) demonstrated that the effect of the Altithermal in northern Colorado was dramatically influenced by elevation; seasonal snowfall and glacial runoff rendered the higher elevations virtually drought-proof and a potential refugium for retreating plants and animals. Benedict and Olson (1978) also argue for two small droughts as opposed to a single continuous drought period. They pointed to the period 7000-6500 RCYBP as the first manifestation of drought, affecting primarily the Southern Plains, and marked by regional shifts in population – generally to better-watered, higher altitudes or along river basins. Similarly, Benedict and Olson (1978) postulated the period 6500-6000 RCYBP is marked by a re-advance of glacial cirques and possibly an increase in moisture across the Plains. The period 6000-5500 RCYBP, however, represents a dramatic decrease in moisture and was potentially the most severe 500-year interval with in the period generally identified as the Altithermal (1979: 180). It is during this time that the Mount Albion complex emerges, which Benedict and Olson argue is a mountain-oriented culture formed in direct response to regional climate change. Drawing upon other lines of evidence, Forman et al. (1995) reviewed the Holocene record of eolian sand and loess deposition across the Great Plains as a means to infer changing precipitation patterns and periods of sustained moisture deficit. More specifically, they argue that periods of dune reactivation are indicative of decreased surface and groundwater resources and decreasing above ground primary productivity because of prolonged (multi-decadal) drought. The decrease in above ground productivity exposes underlying soils to erosion and decreases in surface water limit cooling via evapotranspiration; in other words, droughts on the Great Plains create self-sustaining feedback mechanisms. Patterns in stratigraphic and geomorphic eolian sequences are compared across the western Great Plains to address spatial and temporal patterns throughout the Holocene. Forman et al. (1995) suggests that dunes were mobilized numerous times during the Holocene, with significant, prolonged events in the early-mid Holocene, and numerous, shorter, and more discrete events since 2000 RCYBP.

The eolian evidence of particular interest in this study comes from the dune fields of eastern Colorado, which have been reviewed in detail elsewhere (Forman and Maat 1990; Forman et al. 1992, 1995; Madole 1994, 1995; Muhs 1985; Muhs et al. 1996, 1997, 1999). Dunes from the South Platte and Arkansas River basins, as well as adjoining areas (Nebraska, Kansas) indicate peak eolian mobilization sometime between ca. 7000 and 5000 RCYBP, with noteworthy activity both immediately before and after this period. Additionally, most dunes also show evidence of at least one activation event in the last 2000 RCYBP. The timing of the later events corresponds to an interstitial between the Triple Lakes and Audubon glacial advances in the Colorado Front Range, dated between 3000 and 1850 RCYBP (Benedict 1973).

Clarke and Rendell (2003) use infrared stimulated luminescence (IRSL) of feldspar grains to date dune formation in northeastern Colorado. They and others have noted the sensitivity of dune sands to climate change, and in particular, the formation of parabolic dunes during periods of aridity in which sand is removed from the dry South Platte River bed by strong westerly winds (Holliday 1989; Madole 1994; Muhs and Maat 1993). Specifically, when certain mineral grains (quartz and feldspar) are exposed to light the latent luminescence signal is "bleached" down to negligible levels. Once buried however, the grains begin absorbing ionizing radiation form the surrounding soil matrix, particularly from low concentrations of radioactive substances such as uranium, potassium, thorium, and rubidium. Soil samples are removed under controlled light conditions and the resulting radiation levels are measured. In this way, it is possible to estimate the date of deposition for various sand strata. Thus, their research is aimed at identifying periods throughout the past that were subject to extensive drought.

Clark and Rendell (2003) compare their IRSL derived dates to radiocarbon-dated paleosols that formed within dune formation events at the Friehaufs Hill and Hillrose dunes northeast of Fort Morgan Colorado.

Table 2-1 lists select dated events for periods of aeolian dune activity during the middle Holocene. Collectively, the data represent dated aeolian activity from the western, central, and northern Great Plains, and suggest one or more significant drying events roughly dating between 8,000 and 4,500 RCYBP.

The Late Holocene climatic data (approximately 4,500 RCYBP to present) reflect a general tendency towards increased moisture relative to the Middle Holocene, but also strongly indicate a great deal of variability. Bison populations appear to have dramatically increased during this period, likely a result of a competitive advantage associated with the changing grassland environment (Hill et al. 2008).

Table 2-1: Select dune mobilization events from the Western United States in years BP

Colorado	North Central Nebraska	Central and Western Kansas	Wyoming	New Mexico
4850	4600	5370	4040	4650
6000	5150	5670	4160	
6250	5730	6300		
7750	6500	6700		
	7800			
See Clark and Rendell 2003, Forman and Maat 1990, Forman et al 1992, Forman et al 1995, Madole 1995, Muhs 1985, Muhs et al 1996, Muhs et al 1997, and Muhs et al 1999 for more information				

Much in the same way the warming pattern of the Middle Holocene was gradated in intensity from north to south, the general increase in moisture was also disproportionately experienced across the Great Plains. Broadly, the return to more mesic conditions began in the north, in Saskatchewan, Montana, and Northern Wyoming, sometime between 4500 and 3500 RCYBP (Kay 1998), and progressively moving south, beginning as late as 2500 RCYBP on the Southern Plains of Texas and Oklahoma (Meltzer 1991). Indeed, the Great Plains were more appropriately a mosaic of conditions spread across great distances. Understandably, the specific conditions within the Rocky Mountains were more spatially and temporally variable, again, under the influence of altitude and patterns in seasonal rain, snow fall, and changing glacial conditions.

However, the climatic resolution of the recent past is as much a result of the relatively recent age of the materials as it is increases in the depth and breadth of analytical techniques appropriate for those materials. For example, dendrochronology, or tree-ring dating is capable of identifying individual years within the lifetime of the given tree. By comparison to other tree-ring samples, from both older and younger trees (of the same species, and wherever they can be found, including frozen in ice) analysts can construct very specific dendrochronological sequences (useful for making temporal and climatic inferences) for the recent past. Thus, increases in the magnitude and frequency of climatic oscillations in the last few thousand years may be over exaggerated relative to the more distant past simply because of inherent differences in data and methods. Moreover, the increase in resolution of more recent climatic data sets has also resulted in more spatially and temporally refined paleoclimate reconstructions. Unsurprisingly, reconstructions that are more refined invariably reveal more variation in climate history and highlight the importance of understanding local paleoenvironmental data.

The preceding chapter discusses the physiographic setting and available paleoenvironmental data and inferred trends for the study area. North-central Colorado comprises a large amount of altitudinal, ecological, and physiographic diversity. The spatial boundary of the present study encompasses the short-grass steppe to the east, the central foothills, montane, and alpine zones, and the intermountain basins to the west, and encompasses over 9000 feet of elevation change. The purpose of this chapter is to better orient the reader to the level of diversity within the study area and how that diversity structures subsequent investigations of hearth morphology through space and time.

CHAPTER 3 GREAT PLAINS AND ROCKY MOUNTAIN CULTURAL HISTORY

Humans have inhabited the study area, and northern Colorado more broadly for approximately the last 13,000 years (Chenault 1999). For the purposes of this study, and following Chenault (1999), the history of human occupation in the area is divided up into three periods. Table 3-1 details the date ranges associated with the individual, identifiable cultural periods and sub periods. The following discussion highlights some of the general trends and patterns previously identified for each of these broad cultural manifestations.

Table 3-1: Cultural Chronology of the study area, adapted from Chenault 1999

Stage	Period	Date Range
Paleoindian		13000 – 7500 RCYBP
Archaic	Early	7500 – 5000 RCYBP
	Middle	5000 – 3000 RCYBP
	Late	3000 – 1850 RCYBP (A.D. 150)
Late Prehistoric	Early Ceramic	1850 – 850 RCYBP (A.D. 1150)
	Middle Ceramic	850 – 410 RCYBP (A.D. 1150 – 1540)
Protohistoric		410 – 90 RCYBP (A.D. 1540 -1860)

Paleoindian Stage

Despite the apparently rapid changes in climate and ecology, the archaeological record of the Paleoindian period, testifies to the overwhelming, often exclusive use of big-game animal resources. In Clovis times, the emphasis appears to have been on mammoth and to a lesser extent mastodon and other terminal Pleistocene megafauna (Kornfeld et al. 2010: 209-215). Evidence of bison (*Bison antiquus*) exploitation dominates later Paleoindian sites. In fact, when sampling 29 components from 22 sites across the Central Plains, LaBelle found that bison were present in all components and nearly always the dominant species represented (2005). Numerous late Paleoindian-age large bison kills, usually numbering 60 animals or less, but occasionally numbering in the hundreds of animals (Jones-Miller, Olsen-Chubbuck), dot the Great Plains landscape, and provide a variety of avenues for exploring Paleoindian subsistence and settlement organization.

However, there is still considerable debate as to the exact nature of Paleoindian technological and subsistence organization. Specifically, archaeologists debate the extent to which Paleoindian strategies exclusively emphasized large-animal resources. Waguespack and Surovell (2003; also Surovell and Waguespack 2007) have argued that Clovis hunters were big-game specialists with an evolutionarily derived toolkit that facilitated efficient large animal hunting strategies. On the other side, Kelly and Todd (1988) argue that Clovis hunters were technology-oriented generalist foragers; i.e., they possessed a flexible toolkit that allowed the exploitation of a wide range of resources in a variety of ecological settings – an attempt to explain the phenomenal pan-continental range of early Paleoindians. Both models argue for high residential mobility and large annual ranges of these early peoples, a hypothesis that is in part supported by the extraordinary distances lithic material appear to have been transported.

This notion of Paleoindians as 'high-plains drifters' is not shared by all archaeologists however. LaBelle (2005) has argued, instead, for place-oriented foragers, mapped onto the landscape, and points towards the wide variation in Paleoindian site types, sizes and supposed functions, and the reuse of large campsites as evidence of redundant use of areas and place-oriented landscape use. Bamforth also notes that differences in the organization of communal bison hunting strategies conflate inferences regarding landscape use and mobility that are centered on bison kill site data. Specifically, he argues that it may be useful to "consider a distinction between hunts with predictable and/or fixed aggregation and kill locations, like those carried out in recent times on the Northern Plains, and hunts with predictable aggregation points but unpredictable hunting locations" (2011: 35). In effect, non-redundantly used sites may not necessarily equate to high residential mobility and a lack of seasonal, redundant aggregation, but rather illustrate a variety of ways that landscapes may in fact be redundantly used; it is in light of this point that the simple mobility dichotomy that characterizes much of Paleoindian research falters.

Evidence of Plains Paleoindian plant use has been documented in a few cases across the Great Plains, but is usually restricted to the margins of the Plains proper, along the Rocky Mountain foothills and Lower Pecos region of Texas, for example (LaBelle 2005). Noteworthy among these is the Barton Gulch Site (24MA171), located in southwestern Montana. The site was first discover in 1972 on a perennial stream in the upper Ruby River basin and was systematically investigated by Montana State University in the early 1980's (Armstrong 1993). The site yielded 75 individual features interpreted as a mix of hearths and roasting pits, grouped into 37 distinct clusters representing 4 separate loci of activity. Macrobotanical analysis of soil samples recovered from the features and living floor identified over 30 individual plant taxa and over 2000 individual charred specimens, with *Chenopodium leptophyllum* (slimleaf goosefoot) and *Opuntia polyacanthia* (prickly pear cactus) dominating the assemblage (Armstrong 1993). Nonetheless, this type of clear, unequivocal evidence of Paleoindian plant use is rare. At present, the available data indicates that the late and postglacial Paleoindian environment was one of high megafaunal diversity and low human population; the overwhelming focus of the earliest North Americans was conclusively centered on faunal, often megafaunal exploitation, though there is potentially considerable seasonal and altitudinal variation, and conflating preservation issues.

Archaic Stage

While Archaic sites are rare in comparison to later sites, the available evidence indicates an overhaul of settlement system strategies. Sites such as the Yarmony Pithouse (Metcalf and Black 1999) and the Tenderfoot site (Stiger 2001) indicate that mobility dramatically decreases during this period and there is an overall trend towards more logistical based organization and resource extraction strategies (Binford 1980). Additionally, the dominance of locally available lithic materials across early and middle Archaic sites also indicates that regional movement has decreased and groups have become more localized (Benedict 1978: 137; Metcalf and Black 1999). Archaic subsistence is characterized by a rapid expansion of diet, a dramatic decrease in the use of large artiodactyls resources (Byers et al. 2002), and a concomitant increase in the use of lower order foods. Indeed, the large bison kills (hundreds of animals) that characterized the Paleoindian period disappear, replaced by a small handful of medium-sized bison kills, and restricted to areas that were apparently sheltered from the more severe impacts of the Altithermal; the Hawken site (48CK303) in the Black Hills of northeastern Wyoming is one example of large-scale, early Archaic bison procurement (Kornfeld et al. 2010: 250-252).

Stable carbon isotope analysis of both bone and dentition (Larson et al. 2001; Leyden and Oetelaar 2001) also demonstrated that bison populations appear to have localized during this period, ranging around predictable water sources. Additionally, Byerly (2009) and Hill et al. (2008) have argued for a decrease in animal health and overall body size associated with the shift from more metabolically efficient C_3 to lower metabolically efficient C_4 grasslands and from selective pressure from human predation. In response to the rapid decline in bison populations and health, Archaic peoples turned to a wide variety of plant and small animal resources, elaborating on a pattern that began at the end of the Paleoindian period.

Late Prehistoric Stage

Subsistence practices during the Late Prehistoric are exceptionally diverse, emphasizing large and small game, as well as a wide variety of plants; as expected, bison seem to have been the focus, when available. The Late Prehistoric is characterized by a diverse range of regionally variable adaptations. Groups during this period pursued a broad economy, and an increase in seasonal sedentism among some groups resulted in the establishment of increasingly complex and archaeologically visible trade networks (Gilmore 1999, 2008). The Late Prehistoric period is most noteworthy for the introduction of pottery and the bow and arrow, both potentially borne from the eastern Hopewell tradition of the Midwestern states (Gilmore 1999, Johnson and Johnson 1998). Some groups in the Central Plains also began experimenting with agriculture in the early part of the Late Prehistoric period, culminating with groups practicing intensive agriculture by 1200 RCYBP (Gilmore 1999: 239-240).

The Late Prehistoric period is the best-documented period in Northern Colorado. Gilmore notes that there are more Early Ceramic sites (1750-1000 RCYBP) than all other time periods combined (1999: 181). While the strong representation of this period in comparison to older sites is certainly a function of the age of the components in question, there are general demographic trends between and within individual periods, and taphonomy alone it does not explain the apparent decrease in population in the Middle and Late Ceramic periods (Gilmore 1999).

In conclusion, humans have inhabited the study area, and northern Colorado more broadly for approximately the last 13,000 years (Chenault 1999). For the purposes of this study, the history of human occupation in the area is divided up into three periods with apparent differences in both subsistence and settlement strategies; differences between these periods and the subsequent impacts such differences may have had on thermal feature morphology is discussed in Chapter 8.

CHAPTER 4 METHODOLOGY

The following chapter discusses the thermal feature classification system and some of the methods employed during the present study. The original data used herein derive from the application of specific sampling and excavation field procedures, as well as a variety of laboratory analyses.

Regional Synthesis and Thermal Feature Typology

As mentioned above, little attention has been given to developing a widely applicable taxonomy that is broad enough to encompass the variation in feature shape, design, size and utilized materials, and yet specific enough to detect variations within and between these variables. However, many of these morphological types are regionally specific and thus the taxonomy of hearth morphology must be approached from a variety of scales. For the purposes of this research, I will use a modified form of a system developed by Mark Stiger for the Gunnison Basin of Colorado (2001). Namely, I identify three principle forms that dominate the archaeological record of Northern Colorado: unlined features, fire-cracked rock features (hereafter referred to as FCR features) and rock-lined features.

Unlined hearths are defined as hearths in which no attempt was made to line the sides of the feature. Additionally, they do not contain quantities of rock that would indicate the use of stone as a heating element. These are the most common thermal feature type seen in the archaeological record of Northern Colorado. They require both the least amount of time and materials to construct. Referring to Thom's model (2009), unlined hearth features could serve any number of basic functions: heating for warmth/light, direct cooking over hot coals, and rock-less earth oven processing. To this list we may also add stone boiling and intensive ungulate marrow extraction (reduction of bone to small fragments – presumably for boiling and the extraction of marrow grease), a rather uncommon practice that began in Paleoindian times (Byers 2002). Generally, stone boiling is thought to require two separate, paired features, one for heating stones (which could possibly be interpreted as a FCR hearth), and another rather steep-walled, unlined pit for boiling the water. There are no paired, unlined features (or paired combination unlined-FCR features for that matter) definitively documented in the study area. Moreover, true pits (features as deep or deeper than wide) are similarly non-existent in the study area. Taken together, the available data warrants a review of what we know about stone boiling and a reconsideration of the archaeological signature it produces (or the variability thereof – a project unfortunately beyond the scope of this project). On the other hand, the lack of features of this type could also indicate that people did not practice this processing method in northern Colorado – another promising avenue of future research.

FCR hearths are those in which the hearth fill contains a large quantity of thermally fractured or otherwise altered stone (fire-altered rock, thermally-altered rock) that indicates its use a heating element, that is, as part of an extended, medium-heat, often subterranean, processing strategy (analogous to a luau pit). However, the stone need not be arranged in a way that would indicate the intentional lining of the feature, although that may occasionally be the case. What qualifies a feature as an FCR hearth is explicitly the inclusion of stone in the fill that would indicate its use as a heating element. A ring of stone surrounding an otherwise rock-less hearth would have little practical value as a heating element and the feature is thus not classified as an FCR hearth, rather simply an unlined hearth (in this case with a rim, though this form is rare). The issue is complicated by the fact that the manner in which the feature enters the archaeological record can muddle the distinction between a lined feature and one that has rock in the fill; it is possible that fill rocks can settle in the pit proper and appear to have lined the feature. In that case, further investigation is necessary to demonstrate that the stone has been used in a manner consistent with the function of a subterranean oven that has been heated, buried, and subsequently uncovered, removed and the process repeated, resulting in rocks that are not uniformly burned on the interior surface, but irregularly. There would be little motivation to disassemble and reassemble the lining of a feature if the intent was, in fact, to produce a lining; thus, the interior surface should remain the interior surface throughout the use-life of the feature and the result should be disproportionate burning of stones on that side. Thus, the use of stone as part of earth oven processing should produce noticeable differences in the character and extent of burning that distinguish it from other feature types.

Lastly, rock-lined hearths are those in which a clear intent to line the walls and often floor of the hearth is evident. These occasionally contain small quantities of fire-altered rock, but are distinguished from FCR features (discussed below) in the intentional lining and lack of large quantities of rock in the fill. The model developed by Thoms (2009) does not include a form directly analogous to rock-lined hearths as defined herein. It may be that they fulfilled a function similar to that described as a ‘cook-stone grill’ by Thoms (2009), although that has yet to be demonstrated. In fact, rock-lined features are very enigmatic and the source of much speculation, principally because they often lack diagnostic materials indicative of use. Dan Bach, who has analyzed over 1400 hearth features from Colorado and Wyoming, has noted that they rarely produce macrobotanical remains and has speculated that they may have been used for drying animal hides (Personal communication 10/15/2009). Smith and McNees (1999), on the other hand, analyzed 44 such features from southern Wyoming ranging from 6800 and 2800 cal BP, and postulates that they may have been used for baking biscuitroot. True rock-lined hearths are relatively rare in northern Colorado; in fact, there are only nine included in this study. Elsewhere in Colorado, such as in the Gunnison Basin (Stiger, 2001) and the Central Colorado hogbacks of the Front Range (Johnson and Lyons 1997), these features have reliably turned up in middle Archaic contexts, the same period noted by Smith for the Wyoming Basin. Strangely, the few features in Northern Colorado date to immediately before and after this period. It should be noted, however, that most of these features dating to the most recent periods are from rock shelters and the design may be related to a desire to reflect heat and not a specific food processing strategy.

Additionally, of all the feature types discussed herein, rock-lined features generally express the most care in their construction. It appears in many cases that the stones were shaped in order to minimize the amount of space between them, and they are occasionally in association with slabs that appear to have been used as a cap. Thus, it is possible that these features doubled as storage units, perhaps as part of a two-fold cooking/storing process. Again, this deserves more attention, but is regrettably beyond the scope of this work.

Despite the above discussion, the difference between lined features and FCR hearths is only rarely ambiguous; most lined features in northern Colorado are constructed of large sandstone slabs and readily identified. However, there are cases in which small angular stones are clearly arranged in order to produce a similar effect and are absent from the fill. Thus I feel it is necessary to be explicit about the terminology used and to dispense with the term ‘slab-lined’, which is often used in the literature, in favor of the less form-specific term ‘rock-lined’ to account for those few cases where large tabular slabs were not available and other materials were utilized.

The difference between the system developed by Stiger and the one used here is simply a matter of subdivision; Stiger differentiates between deep and shallow FCR features, delineated largely by width, depth and the number of layers of stone used in construction. I do not feel such a distinction is warranted in this particular study as many of these hearths are revealed simply as piles of rock on the surface after erosion has removed the surrounding soil, thus conflating human intent and site formation processes. A more thorough subdivision of course, may be useful when describing features in well-understood geomorphic contexts or during excavation, but for the purposes of making broad, regional comparisons, too much detail is of little practical value.

I believe this system provides simple criteria, emphasizing deliberate construction strategies and downplays classifications based on size (which is of course complicated by post-depositional processes, both natural, that is, geomorphic as well as cultural, or human caused) that allows for meaningful comparisons to be drawn between features, sites, and regions, and yet is simple enough to be widely applicable.

Feature Excavation

The data for this study come from a variety of sources both published and unpublished, and result from academic and professional cultural resource management. Accordingly, the goals associated with recording a thermal feature differ according to the research design and management context of the resource in question. Accordingly, not all studies have provided the level and type of data desirable for the stated research goals of the present project. As such, I have supplemented the present data set with research and excavations resulting from three years of field experience associated with the Colorado State University archaeological field school, directed by Dr. Jason M. LaBelle. This original data contributes directly to the stated research goals of the present project and principally comprise excavations from the Black Shale Arroyo site (5LR11718), the Shady Grove site (S10-2), the Line Shack Draw site (5LR110), the

Howling Beast site (5LR11585), the Boxelder Arroyo site (5LR11569), the Harvester site (5LR12641), and the Second Arroyo Site (5LR11711).

However, as will soon become apparent, specific thermal feature excavation strategies depend, in large part, upon the discovery context and site-specific preservation goals. Discussions of thermal feature excavation methodologies, outside that context, are of little practical value because the reader cannot appreciate the contextual decision making that ultimately defines the specific excavation and sampling strategy. Accordingly, specific feature excavation strategies are discussed elsewhere (Chapter 5) and presented concomitantly with discussions of site and specific feature contexts.

Laboratory Methods

Radiocarbon dating

Radiocarbon dating is a radiometric dating method based upon the half-life of the naturally occurring radioisotope carbon-14 (^{14}C) and its relationship to carbon-12. Carbon generally has a molecular mass of 12 (Carbon-12; ^{12}C) and comprises six neutrons, six protons, and six electrons (which effectively have no mass). Carbon-12 accounts for nearly 98.9 % of carbon in the atmosphere. However, as nitrogen-14 drifts to the upper atmosphere, solar radiation interacts with the nucleus, causing spallation, and produces the cosmogenic nucleotide carbon-14 (Renfrew and Bahn 2004: 141). Carbon-14 is, for all intents and purposes, chemically identical to carbon-12. Accordingly, it bonds to oxygen to produce carbon dioxide in the same way as carbon-12, and is taken up by plants and animals, in proportions that closely mirror the atmospheric ratios of carbon isotopes (save for the effect of isotopic fractionation, which is corrected for in the lab). Due to the effective relationship between material mass and rates of molecular interaction, carbon-14 decays back to nitrogen-14 at an exponential rate, and produces a fixed half-life interval of approximately 5730 years (Renfrew and Bahn 2004: 141) In other words, regardless of the starting quantity, approximately one-half of the material will have decayed to nitrogen-14 within 5730 years. With that in mind, living things maintain the near-equilibrium balance of atmospheric and organic carbon as long as they exchange gasses with the environment (or eat things that exchange gasses with the environment). However, once the exchange of atmospheric gasses ceases, the isotopic carbon concentrations, and more specifically, the carbon isotope ratios, are subject to change due to the effect of beta decay. Using various methods to estimate and correct for the atmospheric carbon isotope ratios throughout the past, radiocarbon dating measures the current ratio of carbon-14 to carbon-12 and calculates how many half-lives the material must have gone through to produce the measured ratio relative to the presumed starting ratio (Renfrew and Bahn 2004: 141).

Moreover, with regard to radiometric dating, context is king. The natural history of North America is ripe with evidence of massive forest fires. In other words, charcoal is everywhere. Therefore, only charcoal that can demonstrably be associated with spatially discrete evidence of past human behavior can be reliably used for radiometric dating. Moreover, drawing upon the above discussion of the mechanism of radiocarbon dating, there are important differences within an individual sample that necessitate consideration. Colloquially referred to as “the old wood problem”, differences in the source location (part of the tree or woody shrub) of an individual wood or charcoal sample influence the date the material returns. Specifically, woody trees and shrubs grow in an annual cadence, laying ring upon ring of new growth each spring. The outer growth ring is principally responsible for the transmission of water and nutrients, the inner rings provide support, and not transport. Accordingly, inner rings do not exchange gasses with the environment and are, essentially, dead. This is particularly true with regard to radiocarbon dating; once a new ring is laid down, the radiometric clock begins ticking in the inner rings. That being the case, a single log burned in a fire will contain material that, if sampled individually, would return dates spanning the entire lifetime of the tree/limb/branch; in many cases, this can add up to hundreds of years. Therefore, it is imperative that radiocarbon-sampling strategies emphasize small charcoal elements that represent the least amount of growth until the behavioral event of interest (in this case, burning in a manmade fire). Similar issues are possible with dead wood that remains on the surface for an extended time before being utilized by people.

Radiocarbon data are reported as radiocarbon years before present (RCYBP). Given fluctuations in in atmospheric carbon ratios (resulting from climate change and associated differences in the interaction between terrestrial, lacustrine, and atmospheric carbon reservoirs), radiocarbon years before present are not directly translatable to calendar years before present without calibration against independently derived records of atmospheric carbon fluctuations (often established dendrochronological, ice core, and coral reefs records; Renfrew and Bahn 2004: 129-141). For the purposes of presenting a single date, the uncalibrated RCYBP, or calibrated date range midpoints may be used. However, in aggregate, it is important to recognize variation within the depth and breadth of radiometric measurement. In that case, sum probability distributions are preferable to calibrated midpoint dates, as individual midpoints do not take into consideration the breadth of variance within individual dates estimates around the mean (midpoint) value, and may ignore neighboring dates with a similar probability (Eighmy and LaBelle 1996). All calibrations were calculated using CALIB 7.0 and the IntCal13 calibration curve (http://calib.qub.ac.uk/calib/).

Fuel wood analysis

Fuel wood samples were identified by Daniel R. Bach, owner and operator of High Plains Macrofloral, LLC. Samples were identified through comparison to an extent burned wood collection and arboreal literature available at High Plains Macrofloral, LLC. For further information regarding the methods and procedures of wood identification, see Appendix C and Boonstra et al. (2006a, 2006b) and Core et al. (1979).

Macrobotanical analysis

While ethnobotanical approaches to understanding human behavior were well underway in European, and Middle Eastern archaeology by the 1860's, it was not until the early 20th century that systematic archaeological investigations of human plant use expanded and spread to North America. This growth was later fueled by the development of the flotation method in the late 1960's; a process aimed at the recovery of macrobotanical remains form soils and sediments (Pearsall 2000:4). The flotation method expanded the analysis of human plant use beyond those rare contexts that strongly favor preservation of large organic remains, to include trace evidence of human-plant interactions. Shortly thereafter, the technique gained widespread acceptance across the United States and became a mainstay technique in areas like the American Southwest (Pearsall 2000).

Density is the underlying logic behind macrobotanical floatation. The process begins when a soil sample is submerged and agitated in water, thus suspending the soil in the water matrix according to the density of the constituent material. Charred organic material is less dense than water, floats, and is screened off by hand, or siphoned off in a variety of ways. Once removed, the lighter material (known as the light fraction) is bagged, labeled, and hung to dry. Material with a higher density than water sinks and is trapped in a screen at the bottom of the device (known as the heavy fraction). Sterile, that is non-cultural, sediment with a density greater than water sinks through the screen at the bottom of the tank and is discarded. Due to its relative simplicity, flotation has become very popular both in the lab as well as in the field, as any watertight tank and screen can be easily converted for macrobotanical recovery (see Pearsall 2000 for a detailed discussion of different types of flotation).

The flotation system used in this study was developed with the assistance of Dan Bach of High Plains Macrofloral. The device consists of a 5-gallon tank affixed with a bottom-draw water inlet valve (Figure 4-1). The soil sample is placed on a screen at the bottom of the tank. Water fills the tank from the bottom, and submerges the sample. The soil is agitated by hand to free the relevant materials from the soil matrix. The light fraction rises to the surface as the tank fills and is directed through an overflow pipe into a 60 x 60 wire/inch mesh sieve. The heavy fraction is trapped in the screen at the base of the tank and the sediment is screened through. The heavy and light fractions are cleared from the screens and allowed to dry. The remaining sediment is then floated once again to ensure maximum recovery of light fraction materials. Once dry, both fractions are visually inspected by a specialist (in this case, Dan Bach) for the presence of cultural materials (lithics, pottery, shell) as well as potentially associated floral and faunal remains.

Despite its relative simplicity however, it is important to realize the shortcomings and limitations of flotation. Much in the same way it is critical to understand the taphonomic processes that influence the constitution and transformation of the archaeological record, it is also imperative to recognize the way our methods influence archaeological remains, as they become archaeological data.

Authors have noted consistencies and inconsistencies in the preservation and recovery of certain macrobotanical remains, in addition to the observation that plant materials rarely preserve equally (Vandorpe and Jancomet 2007; Wagner 1982; Wright 2005). Building on this weakness, many have turned to exploring the recovery rates of different flotation systems. For example, Wright (2005) explored the recovery rates of various plant species from soils with variable amounts of clay, silt, and sand. She embedded 25 samples of 11 different species in the soil samples and floated them to gauge the recovery rates. Her data indicated substantial differences between soil types and processing time. Similarly, Wagner (1982) seeded soil samples with known quantities of carbonized poppy seeds as a means to test the relative effectiveness of various flotation systems. She found that differences in mesh size and soil type affected hand-agitated flotation systems more dramatically than machine-agitated ones, but neither yielded consistent results, indeed, both systems varied as much as 30 percent between samples and seed types.

Figure 4-1: Basic flotation system used in this study

Additionally, it has been noted that pretreatment methods can have an effect on recovery rates. Pretreatments include such novel concepts as preliminary drying and screening, soaking in weak acidic or basic solutions, boiling, pre-freezing, and even the use of commercial water softener and sonic baths (Piperno et al. 2009). Vandorpe and Jancomet (2007) tested the effectiveness of four pretreatments methods for highly compacted organic sediments. They include heating, freezing, soaking in sodium bicarbonate and heating with 10% potassium hydroxide. They conclude that freezing offers the best option for freeing plant remains from compacted soils. Freezing is the least damaging of the alternatives they tested and does not leave a chemical signature.

Following these experimental approaches to macrobotanical recovery, I have conducted my own experimental trials with a variety of soils, plant materials, and treatments. These experiments were carried out with the same flotation system used in this study, prior to the processing of any archaeologically relevant samples. Preliminary experimentation with the device allowed the opportunity to refine the process and address any issues without compromising the integrity of archaeological samples as well as to establish a baseline recovery rate for several species that are routinely identified in hearths from Northern Colorado. The experiments were carried out with three soils types of varying clay content (the most common source of variability in recovery rates cited in the literature), three charred plant species – goosefoot, Indian ricegrass, and prickly pear cactus (*Chenopodium berlandieri, Acnatherum hymenoides,* and *Opuntia polyacanthia,* respectively), and three treatments: unaffected, 5 freeze/thaw cycles and 10 freeze/thaw cycles. To briefly summarize, while in general, the recovery rates of the soil types were improved by the repeated freeze thaw cycles, there are significant differences between individual plant species. *Acnatherum hymenoides* recovery improved across 10 freeze/thaw treatments between 5 and 30 percent, depending on soil type, with sandy clay-loam expressing the greatest recovery rate increase. Cacti spine (*Opuntia polyacanthia)* recovery was low in general and I did not find any improvement after treatment. However, cacti spines are much more variable in length and thickness than the typical seed. I believe this influenced the degree of charring on an individual basis and ultimately conflated recovery rates because smaller and more thoroughly charred spines have a greater propensity to pass through the collection screen. Lastly, due to modern seed contamination issues, Goosefoot (*Chenopodium berlandieri)* was only reliably tested in sand and recovery decreased by 50 percent after ten freeze/thaw cycles.

It is clear that more research is needed to fully understand the variable recovery rates associated with both different plant materials as well as soil types. At present, the floatation method facilitates the identification of charred organic materials in soils and sediments recovered from a variety of contexts and allow us to make inferences, on an individual basis, of the use of features and areas. The method is, however, still in its infancy. Direct comparisons between features are very problematic given the numerous sources of variability in recovery. Most research is simply oriented towards the identification of materials in a presence/absence fashion. With continued research, it may become possible in the future to develop models for preservation and recovery rates of soils and plant materials that could be used to make quantitative assessments of feature use. Coupled with parallel approaches such as quantitative charcoal recovery (Bach 2005) and the use-life and accumulation of fire-cracked rock (Backhouse and Johnson 2007; Dering 1999; Pagoulatos 1992; Thoms 2009), it may be possible in the future to make inferences about the amount of material processed in a feature, the length of use, and even the sequence of reuse.

Thus, while the insights gained from paleoethnobotany and the flotation method in particular, have proven indispensable in subsistence and paleoenvironmental studies since the 1960s, there is still much work to be done refining our methods and analytical models. With enough research, it may be possible to transform static, singular interpretations into dynamic understandings of the use-life of features, their function, and integration into broader subsistence-mobility strategies of North American hunter-gatherers.

The preceding chapter discusses the thermal feature classification system and some of the methods employed during the present study. For the purposes of this study, I identify three principle feature types: unlined hearths, fire-cracked rock hearths, and rock-lined hearths. The original data used herein derive from the application of specific sampling and excavation field procedures (discussed in more detail in Chapter 5), as well as a variety of laboratory analyses, including radiocarbon dating, and fuel wood and macrobotanical analysis.

CHAPTER 5 THERMAL FEATURE DATA

The following summarizes the hearth feature data utilized in this study, and includes 14 newly excavated and/or sampled hearth features (described in detail below) and a summary of 181 previously-recorded hearth features located throughout the study area (detailed in Appendix A). The data derive primarily from first hand research resulting from the Colorado State University archaeological field school, under the direction of Dr. Jason M. LaBelle, and from published and unpublished data on radiocarbon-dated hearth features. The following data represent only radiocarbon dated features recorded within the study area. The published data include Colorado State Historic Preservation Office (SHPO) files, Cultural Resource Management (CRM) records, existing literature, published thesis and dissertation work, and unpublished data and reports available through the Center for Mountain and Plains Archaeology (formerly Laboratory of Public Archaeology).

Investigations at Black Shale Arroyo (5LR11718)

Though having been known to the local community since the 1930s, the Black Shale Arroyo site (as it would later be called) was not systematically mapped and recorded until 2006. At that time, Dr. Jason LaBelle, director of the Center for Mountain and Plains Archaeology at Colorado State University, began working with the City of Fort Collins to develop a cultural resource management plan for the Soapstone Prairie Natural Area. The 2006 fieldwork included preliminary mapping and collection of artifacts exposed on the surface as well as the GPS location of identifiable thermal features (LaBelle and Andrews 2007).

Investigations at the site continued in 2009 with the work of the Colorado State University archaeology field school. Again, surface mapping and collection of artifacts were the primary goals. More to the point, the arroyo that dissected the site appeared to have expanded in the interim, and threatened to destroy large parts of the archaeological record; in fact, three of the features recorded in 2006 were no longer extant in 2009. In addition to surface mapping and collection, three features were selected for excavation. The first two features (Feature 6 and Feature 16) were large fire-cracked rock hearths and were visible on the surface of the site. Specifically, these features were chosen as they were located along the highest margin of the site and geomorphology indicated they had been exposed for a comparatively shorter period than features further down the arroyo, at lower elevations. The comparatively shorter window of exposure indicated that the features likely retained a greater amount of structural/morphological integrity and represented the best opportunity to collect preserved organic materials. The third feature was selected as it appeared to represent a relatively uncommon, rock-lined, heath feature type. Unfortunately, excavation of the third feature revealed an anomalous, non-cultural configuration of rock; as such, the third excavation will not be discussed in any further detail.

The attributes recorded for the 5LR11718 features include overall size, shape, and design. Archaeologists recorded feature metrics (length, width, depth) for all hearths (excavated or otherwise) as well as brief descriptions of the morphological integrity of the feature (to guide future investigations) and the presence or absence of cultural materials (flakes, tools, bone, charcoal).

All of the features recorded at Black Shale Arroyo are fire cracked rock (FCR) hearths. It should be noted however, that other feature types (that do not include rock), potentially indicative of other activities, are not nearly as erosion resistant as those that include rock, and thus may have been present, but may have been subsequently removed through erosion and other geomorphic processes. However, a systematic geoarchaeological investigation of the area will help address the validity of the site use inferences proposed herein.

Excavations of Features 6 and 16 (5LR11718) were approached with the same general strategy, resulting from nearly identical discovery contexts. All hearth excavations began with the goal of delineating overall feature size, design, and construction material. Additionally, investigators endeavored to locate datable charcoal and soil samples for macrobotanical analysis. The features were prioritized based on integrity and the danger of destruction via the expansion of the arroyo system; in each case, salvage of the entire feature fill was appropriate. Differences in excavation strategy will be discussed below.

Excavations began with measurements of the maximum dimensions of the feature and determinations of the subsequent excavation unit. A grid was set up over each feature dividing the area into four quadrants. In the case of the Black Shale Arroyo, Feature 16 measured 127 cm by 123 cm and required a 150 cm by 150 cm grid; Feature 6 measured 160 cm by 120 cm and similarly required a 150 cm by 150 cm unit. Generally, it is preferable to center the excavation unit directly over the center of the feature, ensuring the feature is equally represented in each quad, thus allowing excavation to progress in a largely symmetrical fashion.

Having established the units, the surface of the feature was mapped using a 50 cm x 50 cm drawing grid and graph paper (Figure 5-1). Every rock larger than 5 cm was plotted. Once mapped, a beginning elevation was recorded for each unit using a total station and an excavation line-level datum was set up. The line-level approach entails the use of an arbitrary datum (the elevation of which is recorded with the total station) and a string line and level to guide excavations in arbitrary 5 cm or 10 cm levels. This method differs from other common excavation strategies that utilize level-by-level total station readings to guide excavations. The line-level method was chosen, as it is faster and more convenient. The total station approach allows the synchronization of excavation levels across a site by tying all units to a common elevation reference – the total station datum. However, since only three excavations were conducted at the site and across a large area, synchronization of unit levels was deemed unnecessary. In addition, when excavating FCR features filled with angular rock, the establishment of precise levels, characteristic of other types of excavations, is not practical.

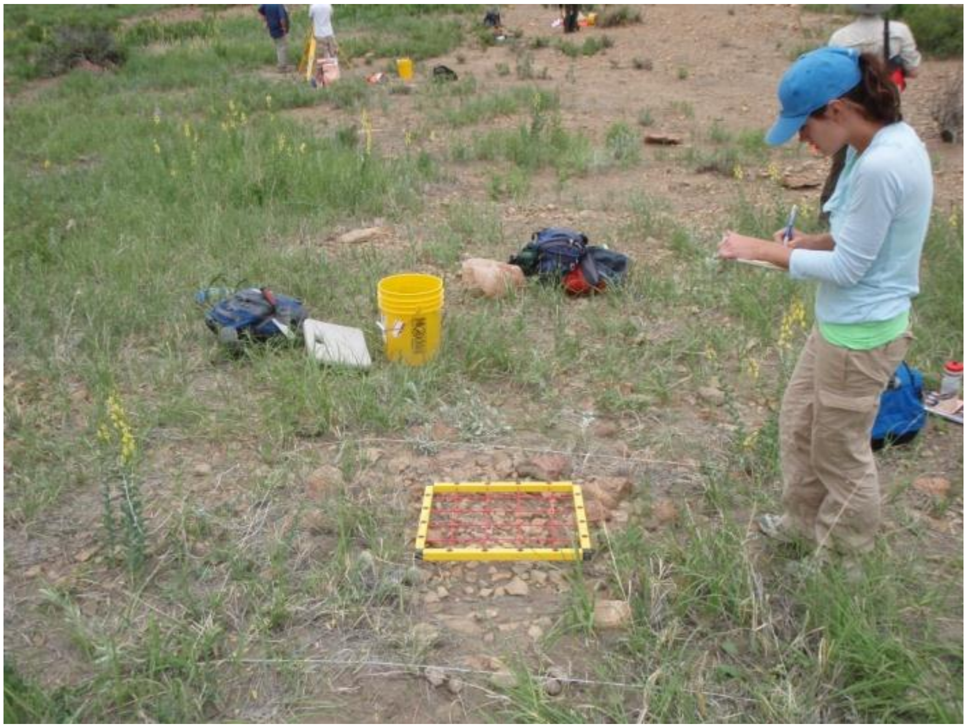

Figure 5-1: 5LR11718 Feature 6 pre-excavation surface mapping

After the datum was established and the surface rock recorded, the excavation began in two quadrants (Figure 5-2). The surface FCR was removed and set aside; the total FCR removed from the feature was eventually counted and massed; future analysis may utilize the data in order to make inferences of feature use intensity and reuse tempo (for a discussion of the application of FCR studies see Backhouse and Johnson 2007, Dering 1999, Pagoulatos 1992, and Thoms 2009). The first two quadrants were excavated in arbitrary 10 cm levels; these quadrants were taken all the way through the feature. A methodological difference arises when excavating different types of features. In the case of FCR hearths the boundary of the feature is clear, as it is defined by the maximum extent of fire-cracked rock. When excavating unlined features on the other hand, the boundary is not always as clearly defined. Thus, when dealing with FCR features it is possible to target only the hearth fill for sampling and to only excavate the hearth proper. In the case of the Black Shale Arroyo features, all excavated hearth contents were bagged and collected for analysis at the Center for Mountain and Plains Archaeology.

Figure 5-2: Excavation of 5LR11718 Feature 16

Feature 6 is large FCR hearth measuring 160 cm x 120 cm and 20 cm deep. The feature is basin shaped with a width the depth ratio of 7:1. Archaeological field school students removed 22 – 2 L bags of sediment during excavation. The feature produced over 24.6 kilograms of fire-cracked rock, mostly from the surface, indicating that erosion has potentially deflated the soil matrix surrounding the feature. No bone or lithics were recovered from either the wet screens or the flotation heavy fractions. Despite the comparatively longer window of exposure, the feature produced a large amount of charcoal; Dan Bach of High Plains Macrofloral, identified charcoal recovered from the feature fill as either saltbush (*Atriplex sp.*) or greasewood (*Sacrobatus sp.*); unfortunately, no other macrobotanical remains were present or identifiable (Appendix C). Beta

Analytic radiocarbon dating laboratory dated the identified samples using accelerator mass spectrometry, returning an uncalibrated date of 1270+/-40 RCYBP.

Feature 16 is large FCR hearth measuring 123.2 cm x 127.5 cm and 11.4 cm deep. The feature is also basin shaped with a width the depth ratio of over 10:1. The feature is exposed along the northwest boundary of the site and is very near the edge of the hillside. The geologic context of the site indicates that this feature has been exposed for the shortest length of time. Colorado State University Archaeological field school students removed 11 – 2L bags of sediment during excavation. All samples were processed using macrobotanical flotation. The feature produced a large amount of charcoal and other organic matter – some of which is certainly modern; in fact, nearly half of the recovered sediment, by volume, was charcoal. Dan Bach of High Plains Macrofloral, identified charcoal recovered from the feature fill as a pine species (*Pinus Sp.*). Beta Analytic radiocarbon dating laboratory dated the identified samples using accelerator mass spectrometry, returning an uncalibrated date of 1060+/-40 RCYBP (Appendix B). Interestingly, the dates from Features 6 and 16 do not overlap at the 2-standard deviation, calibrated range, indicating that these two dates represent at least two separate occupations during the Late Prehistoric period.

Adjacent and possibly related to Feature 16 is Feature 14. This feature is a dense collection of fire-cracked rock. The feature does not appear to be another hearth, as it lacks defined edges is composed of only the smallest size class of stones that have been identified in nearby hearths, suggesting it was not used for the same purpose. Alternatively, I believe the feature is an associated clean-out pile of exhausted FCR from Feature 16. Feature 14 is roughly 2 m northwest of Feature 16, and measures 50 cm x 85 cm. The feature was not excavated; hence, a depth is not available –although the feature does not appear to have a buried component. A charcoal sample was selected for possible future radiocarbon dating. A date corresponding to that measured from Feature 16 would demonstrate the functional interrelatedness of the two features, and testing and/or full excavation would shed light on the functional interpretation of Feature 14 presented here.

Absolute, 14C dates place the features in the late Early Ceramic period of northern Colorado prehistory. These dates are consistent with the date range of recovered diagnostic artifacts and other 14C dates, both at 5LR11718 as well as at sites within the immediate vicinity (S10-2). This period is characterized by the introduction of ceramics (though none have been recovered from these particular sites) and bow and arrow technology.

Dan Bach of High Plains Macrofloral analyzed the macrobotanical (light fraction) materials recovered during flotation. Analysis was directed at identification of fuel wood and any other charred/carbonized plant materials that may shed some light on the function of the hearth feature and/or the specific resources processed therein. The results of the analysis are listed in Table 5-1. A more detailed account of the procedures and results can be found in Appendix C. Specifically, and somewhat surprisingly, Feature 6 was characterized by the apparent use of shrubs as fuel (*Atriplex* sp. – saltbush, or *Sacrobatus* sp. – greasewood). Bach notes that radial and tangential cracks in the charcoal indicate that the fuel was burned wet (green). Additionally, the charcoal represents an uncharacteristically large specimen of the given species. Bach hypothesizes that the plant likely had directly tapped into a water source, that is, a stream or spring (the site today is rather xeric). Feature 16 on the other hand, more typically, was full of pine charcoal (unknown species). Pine is present in limited numbers on site today and is available in the area.

Unfortunately, no other macrobotanical materials were recovered from Features 6 and 16. There are several possible explanations for the lack of charred materials aside from charcoal. First, these features may not have been used for food processing; there are numerous ethnographically documented uses of fire pits. Second, the feature may have been used for food processing, but the materials were thoroughly removed when finished. Lastly, post-depositional forces may have destroyed fragile seed and other fragmentary charred materials, or there may be other unknown problems influencing the recovery rates of certain plant elements; the 5LR11718 archaeological assemblage was entirely exposed on the surface as the site has been badly deflated. Thus, further investigation is necessary to understand the nature and extent of these post-depositional effects.

Investigations at the Shady Grove site (S10-2)

Located a few hundred meters to the north of Black Shale Arroyo, is the Shady Grove site, which contains evidence of prehistoric activity as well as early 20th century homesteading. Previous investigations centered on surface mapping, collection of artifacts, and the GPS location of 13 thermal features.

The 2010 CSU archaeological field school work continued this effort and systematically recorded and collected all surface lithics, bone, and diagnostic historic artifacts and recorded their location with a total station. A rapidly expanding arroyo has similarly dissected the site and a thermal feature (Feature-1) was identified near the edge of the gully and targeted for salvage excavation.

The excavation and sampling strategy mirrored that utilized at Black Shale Arroyo, with the only differences arising from the discovery context. In this case, the unlined feature was intact and buried beneath the surface, and very near the arroyo edge. In fact, the feature was only visible on the surface as a red ring, resulting from the oxidation of iron in sediments adjacent to the feature under prolonged, high heat conditions. Feature 1 salvage required the complete excavation of the first two quadrants to a level below the feature in order to define the maximum extent of the hearth fill (Figure 5-3 and Figure 5-4); the excavation of the remaining quadrants then followed the shape of the feature (Figure 5-5). The soil surrounding the hearth was screened, on site, through 1/8 in mesh and the hearth fill (determined visually) was collected for analysis. After the first two quads were excavated in arbitrary levels, the remaining quadrants were excavated in natural levels that targeted the concentrations of charcoal as identified by the sidewall profiles from the first units. This method is preferable to an arbitrary, defined interval strategy, as the removal of the fill in the largest chunks possible ensures the survival of the fragile macrobotanical materials that may be contained within the soil matrix.

Thermal feature 1 is an unlined hearth measuring 60 cm x 60 cm and is 12.1 cm deep. The feature is basin shaped with a width the depth ratio of about 5:1. The feature was not exposed on the surface; rather, a red oxidation ring on the surface indicated the location of the feature, beneath roughly 10 cm of soil. The feature had not been disturbed, but was also very near the edge of a shallow arroyo, and was in immediate danger of destruction via erosion. Thermal Feature 1 was so near the edge of the arroyo that a centered-grid excavation strategy was impractical as the edges of the unit would be become unstable and collapse during excavation activities. Accordingly, in this particular case, the unit was offset so that the unit edges were in a stable location (some 6-8 inches from the edge of the arroyo) and subsequently, the hearth itself was largely asymmetrically contained within the southeast quadrant.

Figure 5-3: First half of S10-2 Thermal Feature 1 excavation

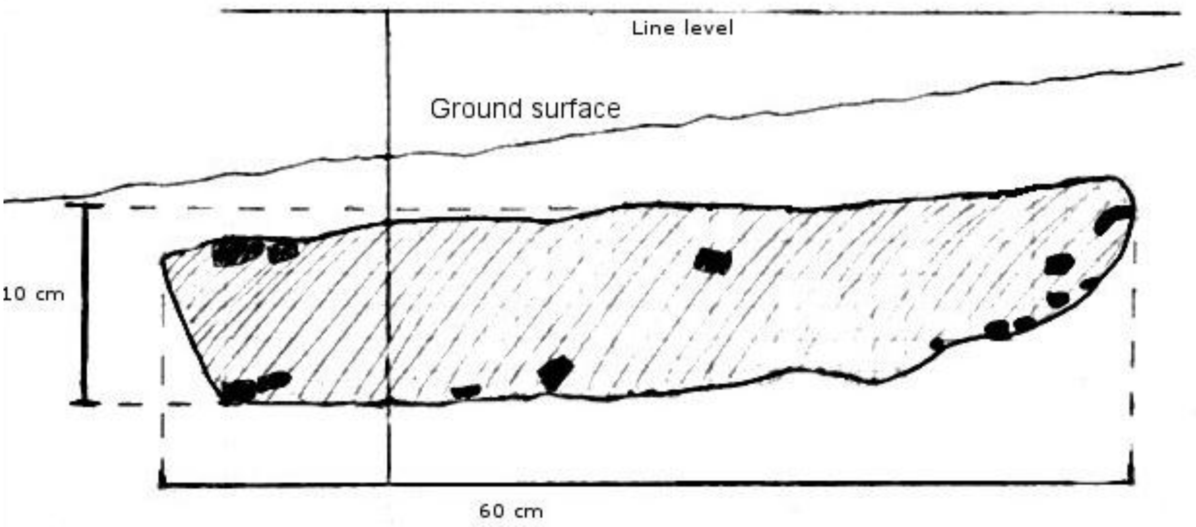

Figure 5-4: Profile illustration of S10-2 Thermal Feature 1 excavation – black marks indicate intact charcoal

Figure 5-5: Excavation of S10-2 Thermal Feature 1

Excavators collected 22 -2L soil samples from the feature fill; sediment clearly not within the hearth proper was screened on site through 1/8 in mesh. Nearly half of the samples were processed using macrobotanical flotation. Preference was given to the lower levels for flotation as they contained the largest quantity of organic materials. The feature produced a reasonable amount of charcoal and other organic matter; Dan Bach of High Plains Macrofloral identified charcoal recovered from the feature fill as a saltbush (*Atriplex sp.*) or greasewood (*Sacrobatus sp.*). Beta Analytic radiocarbon dating laboratory dated the identified samples using accelerator mass spectrometry, returning an uncorrected date 1250+/-40, nearly identical to 5LR11718, Feature 6 (1270+/-40). Thus, it seems the sites, or at least individual components, were occupied and used at approximately the same time. Of course, the archaeological record does not have the resolution to indicate that people were using the same sites at exactly the same time; rather, they were simply both in use in the settlement system at the same time.

Moreover, two additional hearths were radiocarbon dated from S10-2, but not excavated. The features were very similar to those studied at 5LR11718 (Black Shale Arroyo): surface exposed, deflated fire-cracked rock features of varying integrity, but in generally poor condition. The features selected for radiometric dating were thermal features 8 and 13. These hearths, specifically, were selected and analyzed for different reasons.

Feature 8 has been thoroughly deflated, with much of the fire-altered rock distributed across the surface immediately down-slope of the hearth proper (Figure 5-6). However, the very bottom edge of the feature, comprised of dense accumulations of charcoal and embedded FCR, remained and retained structural integrity. Therefore, charcoal and macrobotanical samples recovered from the intact part of the feature would certainly return an age associated with the use of the hearth, and avoid any possible issues with migratory surface charcoal. Moreover, the feature is located very near the center of the artifactual and feature distribution, in an area with a strong Late Prehistoric material signature. Therefore, radiometric analysis of Feature 8 sought to test the agreement between the artifactual and feature data sets, as well as the relationship between neighboring sites S10-2 and Black Shale Arroyo. A radiocarbon sample from feature 8 returned an uncorrected date of 1210+/-40 RCYBP.

Feature 13 (Figure 5-7), on the other hand, was exposed along the northwestern boundary of the site and positioned further up the hill than the other features. The upland discovery context of Feature 13 is similar to that of Feature 6 at Black Shale Arroyo, and indicates a comparatively short window of surface exposure relative to other features. Accordingly, the feature represented the greatest potential to recover intact macrobotanical and other remains. Moreover, field analysis of surface materials recovered in 2010 raised the possibility of horizontally differentiated temporal components. Specifically, while the general site assemblage suggested a

Late Prehistoric age, several artifacts recovered from the western, uphill portion of the site suggested a Late Archaic age determination. While the artifacts were not located near thermal Feature 13, the relative upland setting of the artifacts and feature warranted radiometric analysis of the hearth. As it turned out, the hearth did not date to the Archaic period, but rather returned an age range in accord with the Late Prehistoric era, as previously identified through the artifactual assemblage on-site, as well as through radiometric analysis on Black Shale Arroyo. A radiocarbon sample from feature 13 returned an uncorrected date of 1330+/-40 RCYBP.

Figure 5-6: S10-2 Thermal Feature 8

Both feature dates clearly fall within the Late Prehistoric period of regional prehistory, with radiocarbon ages of 1210+/-40 and 1330+/-40 RCYBP; these data accord well with the known on-site artifact assemblage, the ^{14}C date from the excavated, unlined feature, and excavated features at Black Shale Arroyo. Moreover, the consistency in results between the disparate feature types and their respective discovery contexts indicates that the features contents were not significantly compromised by surface disturbance and the targeted sampling strategy was largely successful.

Figure 5-7: S10-2 Thermal Feature 13

Investigations at the Harvester site (5LR12641)

In May of 2010, Dr. Jason LaBelle advised Jessica Anderson to contact the author regarding excavation of an identified hearth feature (Hearth 2) at the Harvester Site (5LR12641). Pursuant to her thesis research goals, Jessica Anderson thoroughly investigated the Harvester and Weinmeister (5LR12174) sites on the River Bluffs Open Space, in Windsor Colorado (Anderson 2012). The Weinmeister and Harvester sites are situated along the same landform, the Weinmeister site along the base, and the Harvester site on top. Surface inventories of the two sites, resulted in the location of four hearth features. The anthropogenic nature of hearth Feature 2 was confirmed during excavation, and later magnetometer investigations conducted by Dr. Andy Creekmore confirmed the location of several others. Hearth Feature 2 is located along the western slope of the eroding butte top. The feature had been dissected and exposed through surface erosion, and was in immediate threat of destruction, warranting a complete salvage excavation. However, while the general location of the feature was apparent, the specific horizontal extent was less clear. Accordingly, following quadrant subdivision techniques previously discussed, the western (downhill) quadrants were excavated first, so that the feature could be delineated in profile (Figure 5-8). The feature, once excavated, measured 38 cm x 20 cm x12 cm, with a width to depth ratio of 3.2:1, and was largely contained within the northern quadrants. As with previously described excavations, the sampling strategy emphasized on-site, dry screening of exterior fill, and collection of hearth contents for further macrobotanical investigation. A single, small, charred twig was selected for radiometric analysis, and returned an uncorrected date of 1000+/-40 RCYBP.

The material culture recovered from Hearth Feature 2 is by far the largest and most diverse recovered from any feature in the study area. Table 5-1 details the type and quantity of material recovered through of excavation, screening, and subsequent flotation. Hearth features often contain burned bone, which would indicate that animal products were processed in them. This research suggests unlined hearths are more likely to contain intact bone fragments, and presumably, by extension, processed more meat. Few, however, contain more than a handful of fragments, and none rivals the bone density of Hearth 2. Similarly, the flaked stone density has few equals. More importantly however, the feature contained thee bone beads, fourteen shell fragments, twelve pottery sherds, and one groundstone fragment. These items individually range from rather uncommon to rare in northern Colorado. Bone beads have only been recovered from a handful of sites in the study area, namely the Weinmeister Site, immediately adjacent to the Harvester Site, and the Lindenmeier Site (Anderson 2012). Pottery is more common, but most prehistoric hunter-gatherer sites in the area lack ceramics. Moreover, ceramics vessels are often found in concert with groundstone, and generally covary in intensity; similarly, there are more sites in the study area lacking groundstone. Lastly, shell has been recovered from 79 sites within the Arkansas and Platte River Basins (Calhoun 2011) of eastern Colorado, but only nine of those sites are within the study area. Amongst those, shell has only been recovered from one hearth, the one discussed here. Taken together, the artifactual evidence indicates very broad and high intensity behavioral strategies. It is important to note, that the data indicate a great deal of non-subsistence related activities, as evidenced by the apparent manufacture and discard of decorative beads.

The macrobotanical data from Hearth 2 are also impressive. Dan Bach of High Plains Macrobotanical Services analyzed five select light fraction samples. Table 5-1 details the frequency of the various identifiable charred macrobotanical remains. While additional non-charred remains were also observed, Bach notes that without carbonization, small, organic plant parts such as there would not preserve and likely represent modern intrusion. The macrobotanical sample includes remains of *Oryzopsis Hymenoides* (Indian Rice Grass), *Chenopodium sp.,* (Goosefoot)*,* and *Helianthus sp.* (Sunflower). Notably, these three species are colonizing species that proliferate in recently disturbed areas. Given that extended human occupation (i.e. a seasonal campsite) significantly affects the landscape, certain species are known to characterize recently abandoned human camps, and are colloquially called “camp-followers” (Kuznar 1993). Accordingly, repeated (annual, multi-annual) site reoccupation likely forced repeated interaction between humans and these types of plant species. Unsurprisingly, disturbance plants are amongst the earliest domesticated by prehistoric North Americans (Smith and Cowan 1987). The people that inhabited the Harvester site in the past were likely not practicing formal agriculture, but rather likely utilized locally available species that were only indirectly a result of human action.

It also deserves mention that these species (particularly sunflower and goosefoot, which are annual species, meaning they grow, flower, drop seed, and die in a single year) make a very poor source of fuel given a lack of dense, woody material.

Figure 5-8: Profile of 5LR12641 Thermal Feature 2

Investigations at the Line Shack Site (5LR110)

E.B. Renaud and R.G. Coffin first noted 5LR110 in the 1930's. Dr. Elizabeth Ann Morris more thoroughly investigated the site in the 1970's (Morris et al 1979). According to the site card, they identified 10 definite stone circles, 4 probable stone circles, 1 end scraper, 2 side scrapers, 1 corner-notched projectile point, 1 biface, and numerous flakes and glass fragments.

5LR110 was thoroughly surveyed and recorded again in 2006 as part of the CMPA archaeological survey of the Red Mountain Open Space (LaBelle and Bush 2007). At that time, CSU archaeologists spent approximately 4 hours recording 10 features, including 5 prehistoric stone circles (presumably habitation structures), and 5 historic structures. The historic structures include one hand-hewn log cabin, a tin sheepherding cabin and associated outhouse, a stone foundation, and a shallow depression indicative of human modification. Furthermore, archaeologists collected five lithic tools, including one biface, one end scraper, one preform, and two projectile point fragments. The site, as identified in 2006, measured 300 by 100 m in size and extended slightly further to the west than the boundary identified in 1970.

The Colorado State University archaeological field school, under the direction of Dr. Jason LaBelle, returned to 5LR110 in 2009. Following the 2006 survey, a shallow, unlined basin hearth was noted approximately 2 meters below the surface in an arroyo wall, and directly beneath the tin cabin (Figure 5-9). A radiocarbon date taken from the hearth returned a date of 6220+/- 50 RCYBP, dating to the Early Archaic period of regional prehistory, which has recently been increasingly better understood in Colorado (Benedict 1978), but poorly understood across the Great Plains in general (Tate 1999). The discovery of an intact feature of such antiquity necessitated site mitigation efforts before the feature and any other relevant data were lost. Accordingly, archaeologists systematically surveyed, recorded, and collected all cultural artifacts including flakes, tools, bone, and historic materials from the surface as well as three arroyo exposures formed by the stream that dissects the site. Investigators also intensively recorded a variety of features, including two additional prehistoric hearths, two stone circles, the two historic cabins, and the historic foundation and associated depression. Additionally, field school students placed 14 shovel test pits along areas of dense surface material; 13 of the 14 were positive for cultural material, including one, which contained over 150 flakes of the local chalcedony. In sum, the 2009 effort resulted in the recovery of 612 flakes and 28 tools.

Thermal features at 5LR110 were selectively sampled in response to the threat of disturbance or destruction. Archeologists did not encounter thermal features during shovel testing or excavation; features on site were exclusively exposed in arroyo sidewalls. Accordingly, excavation and/or sampling strategies varied according to the condition of the feature and the manner in which it was exposed. At the eastern edge of the site, archaeologists located and dated two hearth features, one a rock-filled basin hearth and the other a shallow basin with a few larger fire-cracked rocks in the lower fill. Both features are roughly 60 cm below the surface, indicating a relatively young age for the surface material on site.

Figure 5-9: 5LR110 Cabin Arroyo Thermal Feature 1

Excavation and sampling of features exposed in an arroyo walls generally centers on specifically mapping, in-situ, the spatial location of the different aspects of the feature, and location of selected samples. In order to do so, the archaeologist must establish a reference line, from which all direction and distance measurements are recorded. The process begins with the establishment of a level baseline beneath the feature and extending beyond the feature horizontally. The baseline is used to draft a profile map of the feature, upon which the location of all stones, intact charcoal and collected charcoal samples, soil discoloration and collected soil samples, and any other material is recorded. It is generally necessary to clean the arroyo wall and exposed feature surface in order to gain a continuous and clean profile of the hearth. Moreover, surface sediments generally have less retained moisture than buried sediments, and therefore may not as readily yield the subtle distinctions in soil color and texture that delineate the presence of a cultural feature. Lastly, it is generally advisable to flatten the feature profile, as three-dimensional variations conflate later attempts to specifically place exact sample locations.

Charcoal and soil samples were recorded, collected, and packaged for later analysis. The quantity of the samples, whether charcoal or feature-fill, depends on the character of the feature itself, and the discovery context.

Including the previously discovered Early Archaic feature and the eastern arroyo features, three hearths were sampled at 5LR110: East Arroyo Thermal Features one and two (EA-TF-1, EA-TF-2) and the Cabin Arroyo Thermal Feature (CA-TF-1). As previously mentioned, Cabin Arroyo Thermal Feature 1 was sampled and returned a measured radiometric age of 6220+/-50 RCYBP.

East Arroyo Thermal Feature 1 was sampled and recorded by the author in 2009 (Figure 5-10). At that time, the feature was exposed in profile in a rapidly eroding arroyo wall. Scant rock was noted in the lower feature fill, and in the sediment slump beneath the feature. Artifacts had been recovered from the same exposure, and the feature was located very near the area of the densest stone circle concentration. Accordingly, the hearth was prioritized for radiometric and macrobotanical sampling, and returned a date of 1270+/-40 RCYBP.

East Arroyo Thermal Feature 2 is a basin shaped hearth, with abundant fire-altered rock in the feature fill (Figure 5-11). Most of the charcoal is beneath the rocks, indicating that the feature may have been capped with rock, or the arrangement represents the remnant configuration after emptying the feature. Some charcoal was noted in between the lower stones. The quantity of stone is similar to that of FCR hearths. In 2009 and 2011, abundant lithic material was noted in-situ, in the wall, and in the slump beneath the feature. In addition, analysis of the heavy fraction of material recovered from the feature fill, following flotation, revealed four small chert flakes. Given the context and integrity of the feature, the hearth appears largely intact and only recently exposed. A total of 15-20 rocks comprise the feature, and average 10 cm in diameter. The hearth is approximately the same level as EA-TF1. Radiometric analysis returned a date of 1110+/-25 RCYBP.

Figure 5-10: 5LR110 East Arroyo Thermal Feature 1 – red line indicates approximated bottom of feature

Additionally, at the far western edge of the site, field school students located cultural material exposed in an arroyo wall several meters below the surface. Upon further investigation, the archaeologists located two buried paleosols over four meters beneath the surface and directly overlying a stratum of large, poorly sorted cobbles. The University of Georgia Center for Applied Isotope Studies analyzed two radiocarbon samples from the paleosols and both returned ages of 3700+/-25 and 3770+/-25 RCYBP. Dan Bach recovered a single, burned, chert pressure flake from the heavy fraction (following flotation) of the upper charcoal layer. Elsewhere on site, cultural components of this age (Middle Archaic) are noticeably missing (Troyer 2012). If the burned flake were in fact part of a cultural horizon, it would suggest the Middle Archaic components are not absent, but simply horizontally distinguished from the earlier and later components. Moreover, the Early Archaic hearth, dated just over 7000 calibrated radiocarbon years BP, is located roughly 100 meters east and only about two meters below the surface. Taken together, the three dates indicate extensive removal and subsequent re-deposition of sediment along the hill system at the far northwestern edge of the site, and comparatively steady, uninterrupted deposition just a short distance away, along the stream corridor proper.

Figure 5-11: 5LR110 East Arroyo Thermal Feature 2

Investigations at the Howling Beast site (5LR11585)

During the 2011 field season, CMPA archaeologists briefly inventoried the site 5LR11585. The site, also located as part of the 2006 survey (LaBelle et al. 2007: 85-88) is located immediately to the east of the Line Shack Draw Site (5LR110), on an arroyo drainage that flows west into Sand Creek. Surface inventories have indicated a great deal of homogeneity between Howling Beast and the Line Shack Site. The artifactual assemblages share some common elements. Namely, pottery is absent from both assemblages (which may reflect a pattern in prehistoric behavior and technology, or simply, patterns in modern vandalism and recreational collecting) temporal diagnostics at both sites indicate similar times of occupation, and raw materials, unsurprisingly, reflect a common source. Additionally, a simple unlined hearth feature was recorded as part of the 2006 inventory; the feature was similarly exposed by arroyo down cutting. With the exception of the Early Archaic-aged feature, the sites appeared to be very similar.

The 2011 reinvestigation comprised a thorough surface inventory and relocation of the 2006 feature. In the process of relocating the hearth, the author identified two previously unrecorded thermal features: an additional unlined, rock-less feature, and a massive fire-cracked rock hearth. Both of the features were exposed in arroyo sidewalls, bringing the total features on site to three. Given the immediate threat of destruction and the fact that 5LR11585 was peripheral to the season's goals, which centered on the testing at 5LR110, the three features were not excavated in their entirety, but systematically sampled and recorded.

Thermal Feature 1 (TF-1) is an unlined, basin-shaped hearth measuring 29.8 cm in width and 15 cm in depth. The width in this example is suspect, as the hearth, at the time of excavation, was exposed on the point of an erosional feature (Figure 5-12), and the original feature diameter, and the position of the remaining material within it, was unclear. The feature lacked any rock within the fill; a single stone was positioned stratigraphically above the feature and was likely part of the post-abandonment burial process.

Figure 5-12: 5LR11585 Thermal Feature 1

Dan Bach analyzed the light and heavy fractions following flotation of a single, 2-liter soil sample. Neither the heavy fraction for the light fraction contained any identifiable cultural material. The University of Georgia radiocarbon laboratory retuned a measured age of 1190+/-25 years RCYBP for a select charcoal sample; Dan Bach identified the charcoal as Ponderosa Pine.

Thermal Feature 2 (TF-2) is a rock-filled, basin-shaped hearth measuring approximately 38 cm in width and 10 cm in depth. The width in this example is suspect, as the hearth, at the time of excavation, was exposed along a rapidly eroding slope (Figure 5-13), and the original feature diameter, and the position of the remaining material within it, was unclear.

Dan Bach analyzed the light and heavy fractions following flotation of a single, 2-liter soil sample. Neither the heavy fraction for the light fraction contained any identifiable cultural material. The University of Georgia radiocarbon laboratory retuned a measured age of 2660+/-25 years RCYBP for a select charcoal sample; Dan Bach identified the charcoal as Ponderosa Pine.

Figure 5-13: 5LR11585 Thermal Feature 2

Thermal Feature 3 (TF-3; Figure 5-14) was exposed high in the arroyo wall, near the head of the arroyo feature. The hearth appeared to have been very recently exposed, as evidenced by an abundance of disturbed soil immediately beneath the feature. TF-3 measured 108 cm in width, and 19 cm in depth. The feature was basin shaped and unlined. The feature contained approximately 18 flat, tabular, sandstone fragments ranging in size from 10-20 cm, and much more had eroded out of the feature and was piled at the base within the disturbed sediment; estimates at the time of excavation hypothesized the feature retained roughly 20 percent of its original volume. None of the recorded rock within the feature was arranged in a way that would indicate intentional lining of the feature. The rock was thoroughly burned, completely encased in charred, organic matter and presumably part of the function of the hearth.

Figure 5-14: 5LR11585 Thermal Feature 3

Dan Bach analyzed a 2-liter sample of the hearth fill for charred macrofloral and other remains. No charred or carbonized macrofloral material was identified. Similarly, the feature heavy fraction did not contain cultural material. A select charcoal sample was identified by Dan Bach as Ponderosa Pine, and the University of Georgia radiometric laboratory returned an age of 1480+/-25 RCYBP (Table 5-2).

Investigations at the Boxelder Arroyo (5LR11569)

Also in 2011, the author and Tia R. Cody, a field school student, sampled another hearth initially located in 2006 (LaBelle et al. 2007: 58-59). The Boxelder Arroyo hearth (5LR11569) was recorded and sampled for radiocarbon dating in 2006 and was located approximately 40 cm below the modern surface and within a buried soil horizon. The feature was exposed in profile, and fire-cracked rock and stained sediment was located in the slump wall immediately beneath the feature. The feature itself contained abundant charcoal fragments and fire-cracked rock; much of the rock was embedded within the wall of the feature (Figure 5-15). It is unclear if the stones were intended as a lining or distributed and embedded throughout the hearth. The latter is suggested by the location of fire-altered stones embedded within the upper stratigraphic margin, as recorded in 2011. A radiocarbon sample collected in 2006 returned an uncorrected date of 660+/-40 RCYBP, and a macrobotanical sample collected in 2011 did not turn up any identifiable materials, macrofloral, lithic, or otherwise. Additionally, the feature was located stratigraphically above at least two visible buried soil horizons (paleosols) at 138 and 210 cm below ground surface; the upper paleosol contained over 100 lithic flakes and charcoal fragments. In 2011, Tia R. Cody collected charcoal samples from both paleosols for radiometric dating. Unfortunately, the lower paleosol did not contain enough charcoal material necessary for a ^{14}C date, though the upper horizon returned a date of 3170+/-25 RCYBP, putting the lithic material towards the end of the Middle Archaic Period.

Figure 5-15: 5LR11569 Boxelder Arroyo Thermal Feature 1

Investigations at the Second Arroyo (5LR11711)

The CMPA, under the direction of Dr. Jason M. LaBelle, also recorded a hearth feature exposed in an arroyo wall in 2007 (LaBelle and Andrews 2007: 143). The feature is located within a north-facing cut-bank arroyo wall, approximately 9.5 meters above the drainage bottom, and approximately 2 meters below the modern surface. The feature, as recorded in 2007, included seven stones ranging 10-20 cm in diameter, and abundant stained sediment within the feature fill (Figure 5-16). The CSU archaeological field school visited the site in 2009 and returned to sample the feature shortly thereafter, in 2011. At that time, the feature was eroding so rapidly that the wall below the hearth was covered in eroded ash, stained sediment, and charcoal; the field school students collected charcoal for radiocarbon dating and sediment for macrobotanical and fuel wood analysis. Upon detailed analysis, the feature is classified as a rock-filled hearth, and is organized with flat-sided stones throughout the fill, but not in the walls or floor of the feature. More to the point, the stones appear to have been arranged atop the charcoal fill, and the angular surfaces may have been a selected feature, or the result of heating and fracturing processes. The charcoal sample was identified as either Saltbrush or Greasewood, and returned an uncorrected date of 1950+/-25 RCYBP. No cultural material was recovered from either floated fraction.

Figure 5-16: 5LR11711 Thermal Feature 1

Table 5-1: Summary of macrobotanical analysis for sampled and/or excavated features – grey cells are not hearth features, but included for context

Site	Feature	Light Fraction	Heavy Fraction	Fuel
5LR110	Cabin Arroyo 1	Currently unanalyzed	Currently unanalyzed	Currently unanalyzed
5LR110	Charcoal Feature 1	Analyzed, nothing found	One flake	Ponderosa Pine
5LR110	Charcoal Feature 2	Analyzed, nothing found	Analyzed, nothing found	Ponderosa Pine
5LR110	East Arroyo 1	Currently unanalyzed	Currently unanalyzed	Currently unanalyzed
5LR110	East Arroyo 2	Analyzed, nothing found	Four flakes	Currently unanalyzed
5LR11569	1	Analyzed, nothing found	Analyzed, nothing found	Currently unanalyzed
5LR11569	Charcoal Paleosol 138 BGS	Unanalyzed - not a feature	Unanalyzed - not a feature	Analyzed, no ID
5LR11569	Charcoal Paleosol 210 BGS	Unanalyzed - not a feature	Unanalyzed - not a feature	Analyzed, no ID
5LR11585	1	Analyzed, nothing found	Analyzed, nothing found	Ponderosa Pine
5LR11585	2	Currently unanalyzed	Currently unanalyzed	Ponderosa Pine
5LR11585	3	Currently unanalyzed	Currently unanalyzed	Juniper
5LR11711	1	Analyzed, nothing found	Analyzed, nothing found	Saltbush or greasewood
5LR11718	6	Analyzed, nothing found	Analyzed, nothing found	Atriplex sp. or Sacrobatus sp.
5LR11718	16	Analyzed, nothing found	Analyzed, nothing found	Pinus sp.
5LR12641	2	See discussion in text	See discussion in text	Saltbush or shadscale
S10-2	1	Currently unanalyzed	Currently unanalyzed	Currently unanalyzed
S10-2	8	Unanalyzed - poor context	Unanalyzed - poor context	Unanalyzed - poor context
S10-2	13	Unanalyzed - poor context	Unanalyzed - poor context	Unanalyzed - poor context

Table 5-2: Summary of radiometric analysis for sampled and/or excavated features – dark grey cells are not hearth features, but included for context

Site	Feature	Uncorrected 14C	Corrected 2-sigma 14C Range (cal BP)	Corrected 2-sigma probability	Lab ID
5LR110	Cabin Arroyo 1	6220+/-50	7257-6998	1.00	BETA 265328
5LR110	Charcoal Feature 1	3700+/-25	4096-3973	0.94	UGA 10292
5LR110	Charcoal Feature 2	3770+/-25	4237-4084	0.98	UGA 10291
5LR110	East Arroyo 1	1270+/-40	1172-1288	0.86	BETA 265327
5LR110	East Arroyo 2	1110+/-25	961-1063	1.00	UGA10290
5LR11569	1	660+/-40	553-677	1.00	BETA 247835
5LR11569	Charcoal Paleosol 138 BGS	3170+/-25	3449-3361	1.00	UGA 10288
5LR11585	1	1190+/-25	1056-1181	0.98	UGA 10285
5LR11585	2	2660+/-25	2796-2746	0.95	UGA 10286
5LR11585	3	1480+/-25	1313-1405	1.00	UGA 10287
5LR11711	1	1950+/-25	1858-1949	0.92	UGA 10284
5LR11718	6	1270+/-40	1172-1288	0.86	BETA 287894
5LR11718	16	1060+/-40	923-1057	1.00	BETA 287895
5LR12641	2	1000+/-40	796-975	1.00	BETA 284074
S10-2	1	1250+/-40	1072-1278	1.00	BETA 288156
S10-2	8	1210+/-40	1055-1263	0.98	BETA 290565
S10-2	13	1330+/-40	1181-1307	1.00	BETA 290566

The Regional Dataset

In addition to the fourteen hearths and seven sites discussed above, the present study includes an additional 181 radiocarbon-dated features representing 65 individual archaeological sites. These sites were studied by a combination of academic, federal, and private cultural resource managers. In nearly all of these cases, the impetus for investigation is federal regulatory compliance. The structure of cultural resource management, as defined by federal law (specifically section 106 of the National Historic Preservation Act), is organized at the state level, and overseen at the federal level by the National Park Service and the Advisory Council on Historic Preservation. Archaeological resources within a given state are organized at the county level. Local sociopolitical differences often result in patterned differences in land use and resource development between counties, and by extension the exposure of archaeological resources. Therefore, in a multi-county study, such as this one, it is imperative to understand differences in the type and quantity of data resulting from geopolitical boundaries.

Table 5-3 lists details of the type and quantity of prehistoric archaeological excavations for the five counties used in this study. The data was obtained from the Colorado State Office of Archaeology and Historic Preservation in November of 2013. The counties range in size from 1918 to 10396 square kilometers, and contain between 683 and 2740 prehistoric archaeological sites. Despite similarities in the range of values, the density of sites varies widely. Grand County, for example, contains the most sites and is the third largest county by area. Weld County is a close second in empirical number of prehistoric sites, but is over twice the size of Grand County, resulting in a density of 0.2 prehistoric sites per square kilometer, relative to the 0.6 sites per square kilometer in Grand County. Despite the wide differences in number of sites and site density per county, collectively the counties fall well within the total range of variation. In fact, when ranked against all Colorado counties (n=64), Boulder, Grand, Jackson, Larimer, and Weld rank between 13th and 31st in terms of the total number of sites, with an average rank of 20th statewide.

Table 5-3: Type and quantity of archaeological excavations by study counties

County	Total Sites	Area (km^2)	Sites/ km^2	Site Rank	Total Tested	Percent Tested	Tested Rank	Total Excavated	Percent Excavated	Excavated Rank
Grand	2740	4839	0.6	13	237	8.6	4	30	1.1	9
Weld	2345	10396	0.2	15	102	4.3	11	35	1.5	8
Larimer	1552	6816	0.2	20	48	3.1	21	23	1.5	13
Jackson	1120	4195	0.3	24	39	3.5	25	0	0.0	52
Boulder	683	1918	0.4	31	23	3.4	33	13	1.9	18
Average	1688.0	5632.8	0.3	20.6	89.8	4.6	18.8	20.2	1.2	20.0

Additionally, the counties vary in the number of sites that have been more thoroughly tested and excavated. In terms of the number of tested sites, the counties range between 23 and

237 in empirical number and vary between 3.1 and 8.6 percent tested. Compared to other Colorado counties, the study areas rank between 4th and 33rd with an average rank of 18.8. In terms of the number of intensive excavations, the counties range between 0 and 35 in empirical number and vary between 0.0 and 1.9 percent excavated. Compared to other Colorado counties, the study area counties rank between 8th and 52nd, with an average rank of 20 (Table 5-3).

Table 5-4 and Table 5-5 list the five study counties, as well as the top five ranking and lowest five ranking in Colorado, in terms of the total number of sites tested and excavated. While the study area generally ranks in the top half in comprehensive archaeological research, collectively, the units approximate the total range of variation in terms of number of sites tested and excavated. While the intent of the study area boundary was to provide a solid cross-section of the ecological diversity of the Southern Rocky Mountains, the counties are a good representation of Colorado more broadly. It is not my intent to argue that the specific results of this study are directly applicable to other areas within the state or region, but rather illustrate that the counties used are not unusual or exceptional, and that similar inquiries elsewhere in the state are equally viable.

Table 5-4: Top five, bottom five, and the five study counties ranked by number of prehistoric sites tested (as of Nov, 2013)

County	Number of Sites	Sites Tested	Sites Tested Rank	Sites Tested Percent
Montezuma	20418	467	1	2.3
Las Animas	7577	382	2	5.0
Moffat	5954	351	3	5.9
Grand	2470	237	4	9.6
Mesa	9035	193	5	2.1
Weld	2345	102	11	4.3
Larimer	1552	48	21	3.1
Jackson	1120	39	25	3.5
Boulder	683	23	33	3.4
Broomfield	12	1	60	8.3
San Juan	92	0	61	0.0
Washington	55	0	62	0.0
Gilpin	13	0	63	0.0
Phillips	6	0	64	0.0

Table 5-5: Top five, bottom five, and the five study counties ranked by number of prehistoric sites excavated (as of Nov, 2013)

County	Number of Sites	Sites Excavated	Sites Excavated Rank	Sites Excavated Percent
Montezuma	20418	373	1	1.8
Moffat	5954	128	2	2.1
La Plata	5511	103	3	1.9
Las Animas	7577	72	4	1.0
Montrose	6865	67	5	1.0
Weld	2345	35	8	1.5
Grand	2470	30	9	1.2
Larimer	1552	23	13	1.5
Boulder	683	13	18	1.9
Jackson	1120	0	52	0.0
Prowers	47	0	60	0.0
Crowley	14	0	61	0.0
Gilpin	13	0	62	0.0
Broomfield	12	0	63	0.0
Phillips	6	0	64	0.0

CHAPTER 6 ANALYSIS

The following chapter presents the empirical data drawn from the synthesis of previously excavated hearth features as well as the original data generated as a result of the efforts of the 2009, 2010, and 2011 archaeological field schools. The chapter comprises two parts. The first part discusses the spatial and temporal distribution of aggregate and type-specific thermal features across the study area. The second part of the chapter discusses variation in feature morphology through both space and time.

Spatiotemporal Distribution of Feature Types

Figure 6-1 presents the sum probability distribution for 193 radiocarbon dates, representing all dated hearths used in this study and comprising all feature types and all elevation ranges. The data presented here reflect the sum of all the probability values associated with individual calibrated date ranges, arrayed by individual year. The probability distribution highlights periods in the past where there is the both the greatest (with the potential to exceed 1) as well as lowest cumulative probability for prehistoric utilization of hearth features (see Eighmy and LaBelle 1996). Broadly, the most recent periods contain the greatest evidence of feature use and there is a steady decrease in feature representation associated with progressively older deposits (there are methods available that attempt to correct for this, but are beyond the scope of this work – Surovell et al. 2009). However, there are exceptions to the trend, both positive and negative. Times with greater representation may indicate periods and conditions that favor preservation of archaeological materials, or simply periods with more people, and perhaps organized in ways that increase the strength of the overall archaeological signature (larger groups, more diverse behavior and activities, better sampling). Conversely, periods with less representation may indicate times that favor destruction of archaeological materials, or simply may represent fewer people on the landscape. There are a few noticeable periods where the strength of the hearth signal on the landscape is strong relative to other periods. However, due to the relative decreased effect of taphonomy on younger archaeological deposits, and the broad trend towards increasing population density across North America through time, increases in the representation of hearth use through time is clearly also to be expected. That being the case, unexpected deceases in the sum probability of hearth use through time are more immediately evident, and perhaps more informative. Making considerations for the sparse Paleoindian record and propensity for poor and inconsistent representation in the record, there are three broad periods where hearth feature representation is strikingly low relative to adjoining times. These include the periods dating around 5800 cal BP, 2600 cal BP, and 800 cal BP (A.D. 1150) or the Early Archaic, middle-Late Archaic, and late-Late Prehistoric Periods respectively. The thermal feature record reaches zero (no hearths with calibrated date ranges overlapping that time) at three points throughout the past. Table 6-1 details the three periods where there is no hearth representation. The gaps range in breadth from 85 years to 22 years. The period 9007 to 9029 cal BP is the shortest, and may not represent as strong a deviation from the general pattern given the paucity of dates from this period, the low sum probability representation of adjacent times, and the comparatively brief hiatus. More notable are the periods 5661-5746 cal BP and 5834-5868 cal BP, which collectively account for 119 years without any representation within the range 5661-5686 cal BP (207 years; Figure 6-2).

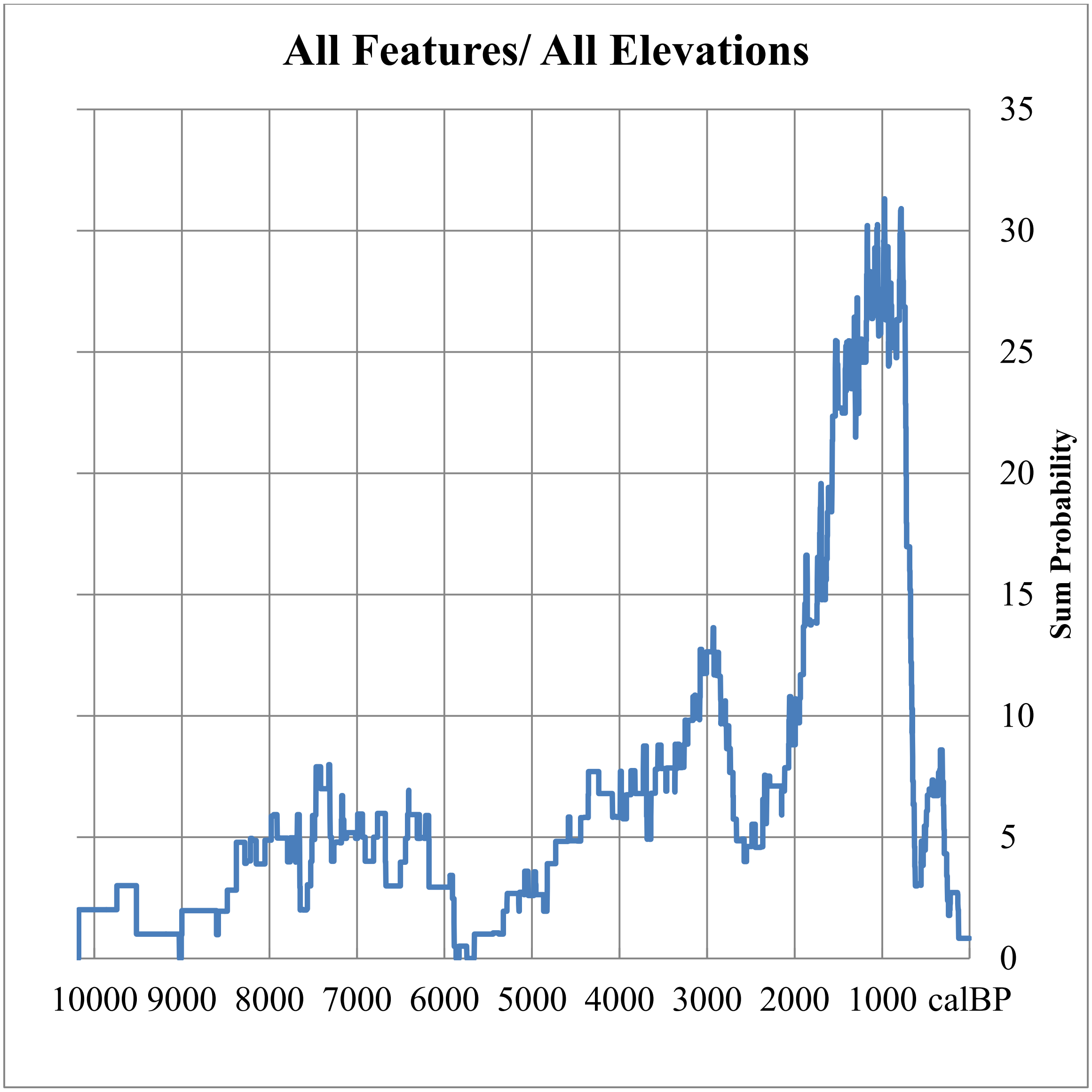

Figure 6-1: Sum probability distribution of 193 radiocarbon dated hearths

Table 6-1: Periods without representation in the 14C hearth record in cal BP

Start cal BP	End cal BP	Duration (years)
5661	5746	85
5834	5868	34
9007	9029	22

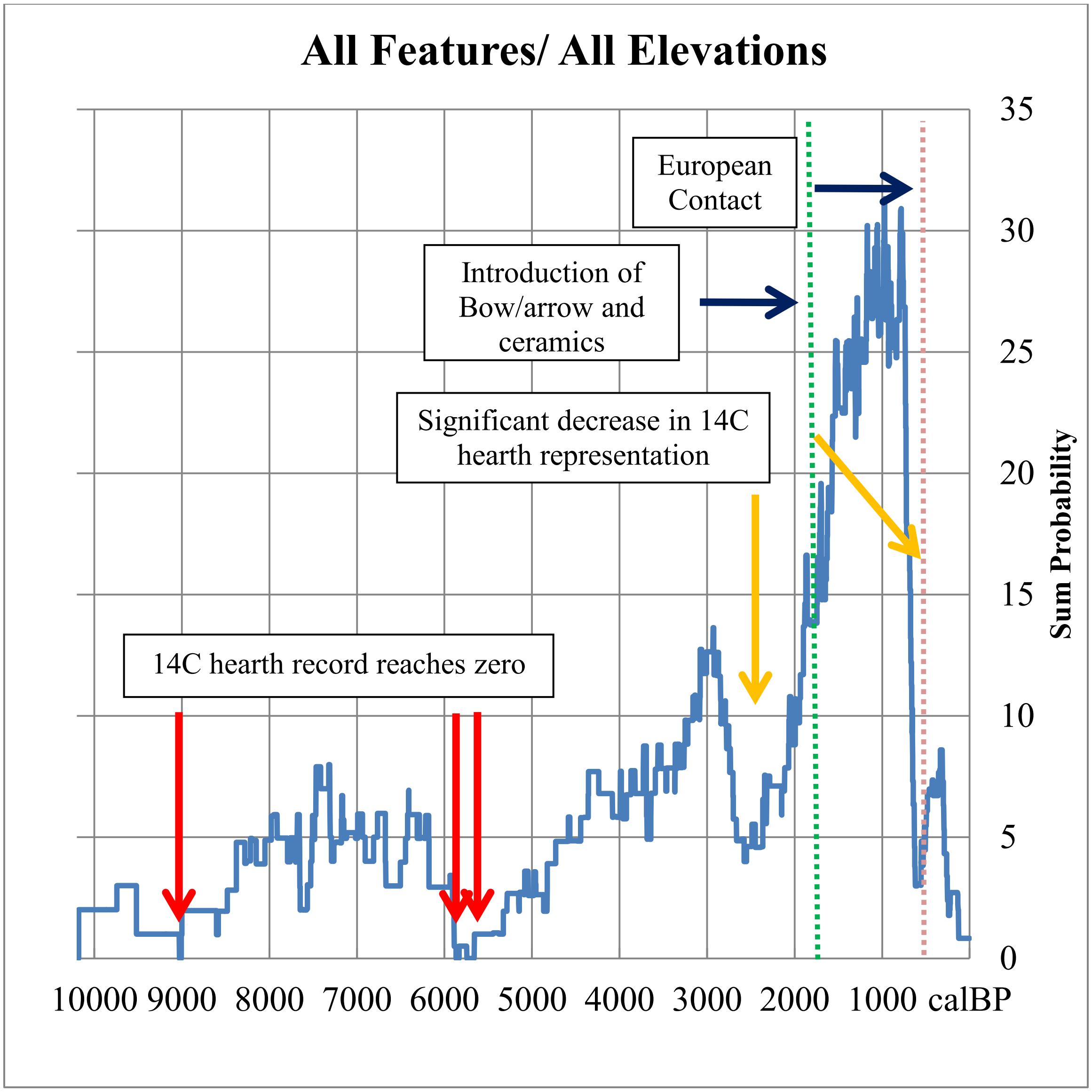

Figure 6-2: Noteworthy periods within the sum probability distribution of 193 dated hearths

Turning to the sharp decreases in hearth representation in the more recent past, there are a few points worth noting. First, while the relative decrease dating to the Late Archaic Period, or the period around 2800 cal BP, is similar to that dating to the Early Archaic Period, the rate at which hearth representation decreases in the Late Archaic is substantially faster. In fact, the initial drop dating to the Early Archaic Period takes place in two, equally spaced intervals of approximately 250 years. On the other hand, the drop dating to the period around 2800 cal BP is greater, and takes place, uninterrupted, in about half the time. Following decrease, the rate of increase in the period following 2800 cal BP is also faster than anything previously recorded. There is a steady and unprecedented increase in feature representation up to the zenith, dating just after 1000 cal BP. Major technological innovations take place during this time, and include the introduction of the bow and arrow, and ceramic technology (Gilmore 1999; Johnson and Johnson 1998), which appear near synchronously around 1850 cal BP (Figure 6-2). This period has elsewhere been demonstrated to contain the largest and most robust archaeological record, suggesting both increasing population density permanence (Gilmore 1999: 181). While the prevalence of sites of this age is certainly due to the recent age of these deposits and the concomitant decreased risk of destruction, a strictly taphonomic interpretation does not resolve the influence of bow/arrow and ceramic technology, and does not explain the rapid increase between 2800 and 1000 cal BP, and, more importantly, the sharp decrease thereafter. No decrease in hearth representation (in terms of rate or empirical difference) rivals the one witnessed during the last 1000 years, and centered on 800 cal BP. There is a slight return in the number of hearths represented on the landscape around 600 years ago, but the increase is reversed 350 years ago and likely a result of contact and subsequent displacement by Europeans.

Figure 6-3 illustrates the ^{14}C sum probability representation of the feature types discussed in the study –unlined, fire-cracked rock (FCR), and rock-lined hearths. Differentiating the feature types in this way allows comparison of the contribution of each feature type at various points throughout the past. Unlined features (n=93) appear first and are the most frequent feature type overall. The earliest ^{14}C dated hearth in the study area comes from the site 5GA151, and appears sometime between 9520 and 10180 cal BP. The earliest feature, and in fact, the earliest twelve features are all unlined (Figure 6-3). The first FCR hearth (n=81) appears between 7794 and

8092 cal BP, and the first rock-lined feature (n=9) shortly thereafter (between 6676 and 7485 cal BP). Unlined features continue to proliferate until approximately 6400 cal BP, at which time unlined hearths decrease significantly, and disappear entirely around 6150 cal BP. Unlined features do not reappear for approximately 1000 years, around 5200 cal BP. On the other hand, FCR hearth frequency rises in the absence of unlined hearths, and maintains a nearly two-fold presence over other features until around 4050 cal BP (Figure 6-3). Shortly thereafter, unlined features increase in frequency and surpass FCR hearths once again. All feature types are well represented around 3000 cal BP, but decrease significantly with the aforementioned widespread decline dating around 2800 cal BP. Finally, the period between 2200 and 800 cal BP witnesses the fastest growth and largest representation of unlined and FCR hearths; rock-lined features double in frequency, but remain marginal to the two principle feature types.

For the purposes of understanding the influence and ecological implications of elevation on the timing and distribution of feature types through time, the data set has been divided into three elevation ranges. Empirically, the study area elevation ranges from 1400 meters to just over 4500 meters; for the purposes of analysis, the data set has been divided into three groups: up to 2000 meters, between 2000 and 3000 meters, and above 3000 meters. These ranges roughly correspond to three large ecosystems of Northern Colorado: the plains and foothills, the mountain zone, and the alpine/subalpine. Importantly, tree limit, that is the boundary between the mountain zone and the subalpine, as well as the interface of the foothills and plains varies now and certainly has varied in the past (Chapter 2 and 3). Accordingly, a strict adherence to modern ecotonal boundaries and associated elevations disregards past variation and the relationship to feature morphology and distribution. Therefore, coarse 1000 meter units are used, and assumptions made about their respective regions, but in a general manner; it is my opinion that exact boundaries are unnecessary, and the broad elevation patterns are more important.

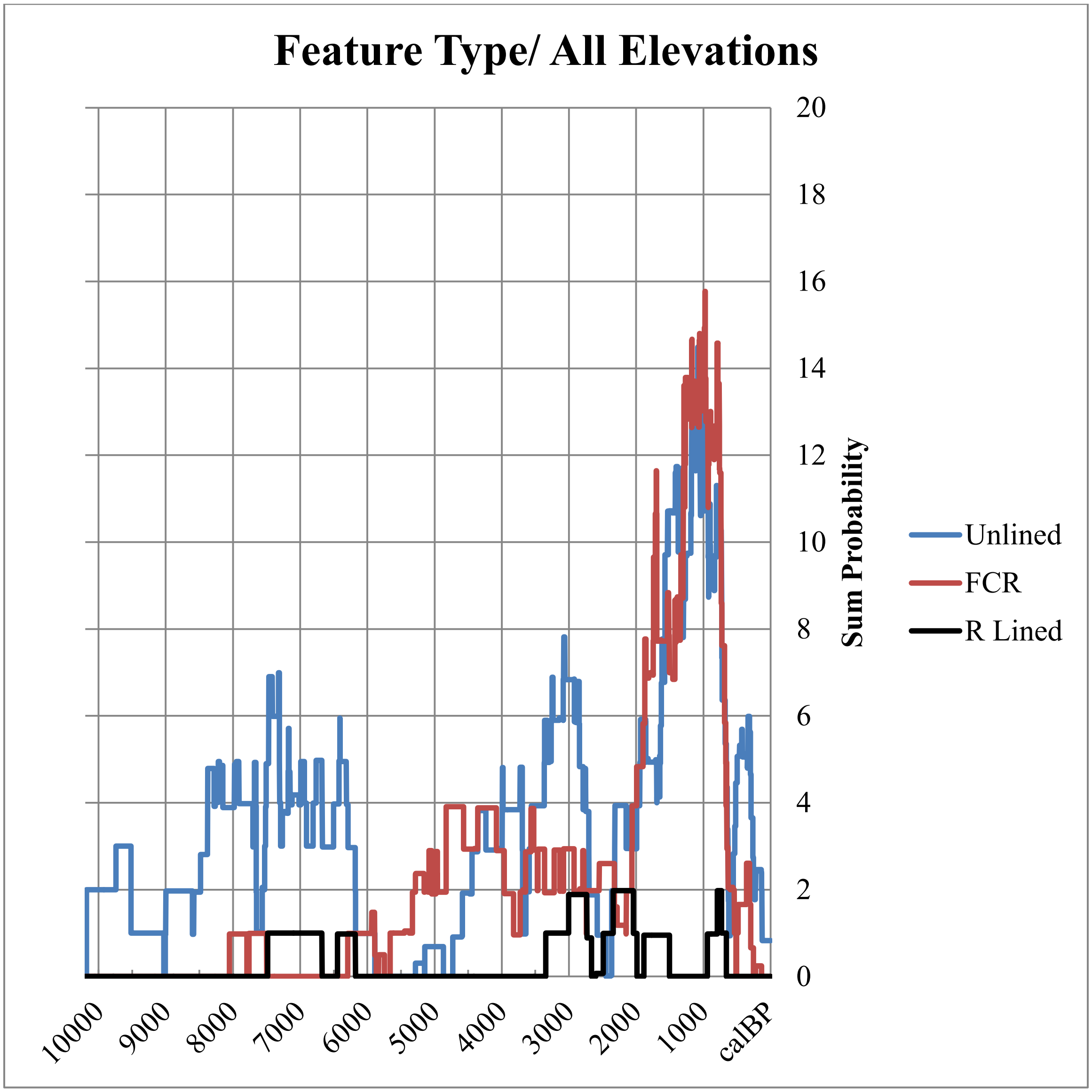

Figure 6-3: Sum probability distribution of features by feature type – unlined, fire-cracked rock, and rock-lined

Table 6-2 details summary information on the characteristics of the three elevation ranges used herein. Unsurprisingly, the lowest elevation is the best represented, with 3.3 million acres, or just under 48 percent of the study area. Areas between 2 and 3 kilometers in elevation make up approximately 40 percent of the study area, and comprise 2.79 million acres. Lastly, areas above 3 kilometers number 846 thousand acres, or about 12 percent of the five-county study area. There are 73 individual sites and 193 individual dated hearths in study area. If site and feature distributions are independent of elevation, we would expect to see site and feature frequencies across the given elevation ranges that mirror their proportion of the landscape. For example, the lowest elevation range, accounting for nearly half of the study area, should contain approximately one-half of the total number of sites and features. Table 6-2 details the expected and actual number of hearths and sites across the three elevation ranges. A simple chi-squared test of independence can be used to assess whether site and feature distributions are independent of elevation (in terms of human behavior, no difference in the way hearth features are used within sites across different elevations). The values returned from the chi-squared test represent the chance of committing a type 1 error (incorrectly rejecting the null hypothesis – in this case: there is no relationship between elevation and site/feature distribution) and assuming a relationship that really does not exist. Therefore, a limit to the acceptable chance of committing an error is specified beforehand. This study uses a 0.05 (or 5 percent) alpha (designator given to the acceptable limit); there is not sufficient evidence to reject the null hypothesis when the test returns values greater than 0.05. Turning to hearth and site distribution, there is enough evidence in both cases to reject the null hypothesis and recognize a relationship between elevation and distribution; there are differences in the way hearths are distributed across different elevation ranges.

Table 6-2: Chi-square test of feature distribution independence across three elevation ranges – red values indicated actual frequencies lower than expected, green values indicate frequencies higher than expected

Elevation	Area acres	Area percent	Actual		Expected		Chi Sq. Value	
			Sites	Hearths	Sites	Hearths	Sites	Hearths
<2000	3,315,661	47.7	36	100	35	92	0.048	0.0007
2000-3000	2,790,929	40.1	22	56	29	77		
>3000	846,388	12.2	15	37	9	23		
Sum	6,952,977	100	73	193	73	193		

Figure 6-4 illustrates the distribution of all aggregated feature types across the elevation ranges. The same periods of relative scarcity and abundance are clearly visible, but there are differences in what elevation ranges features are concentrated at various points throughout the past. First, the middle and upper elevations are represented first. This is particularly interesting given the low proportional area of the highest elevations. Dated hearths are nearly absent on the plains and foothills (below 2000 meters) until about 8400 cal BP. Additionally, dated hearth representation at the lowest elevations decrease first and lead in the first big drop in feature representation (5600-5800 cal BP), followed closely by the upper and middle elevation ranges. During the near feature hiatus, the 2-3 km range maintains the strongest hearth signal (albeit low) and is the first to begin to increase again, just before 5000 cal BP. Thereafter, the highest elevation maintains a small representation, while the middle and lower ranges rise and fall in concert, through the increase around 3000 years ago, the decrease shortly thereafter, and into the exceedingly well represented Late Prehistoric Period. During that time, hearths on the plains and in the foothills increase sharply, to the highest value of any elevation, at any time. The 2-3 and 3+ kilometer ranges similarly increase to their highest respective values around 1000 years ago.

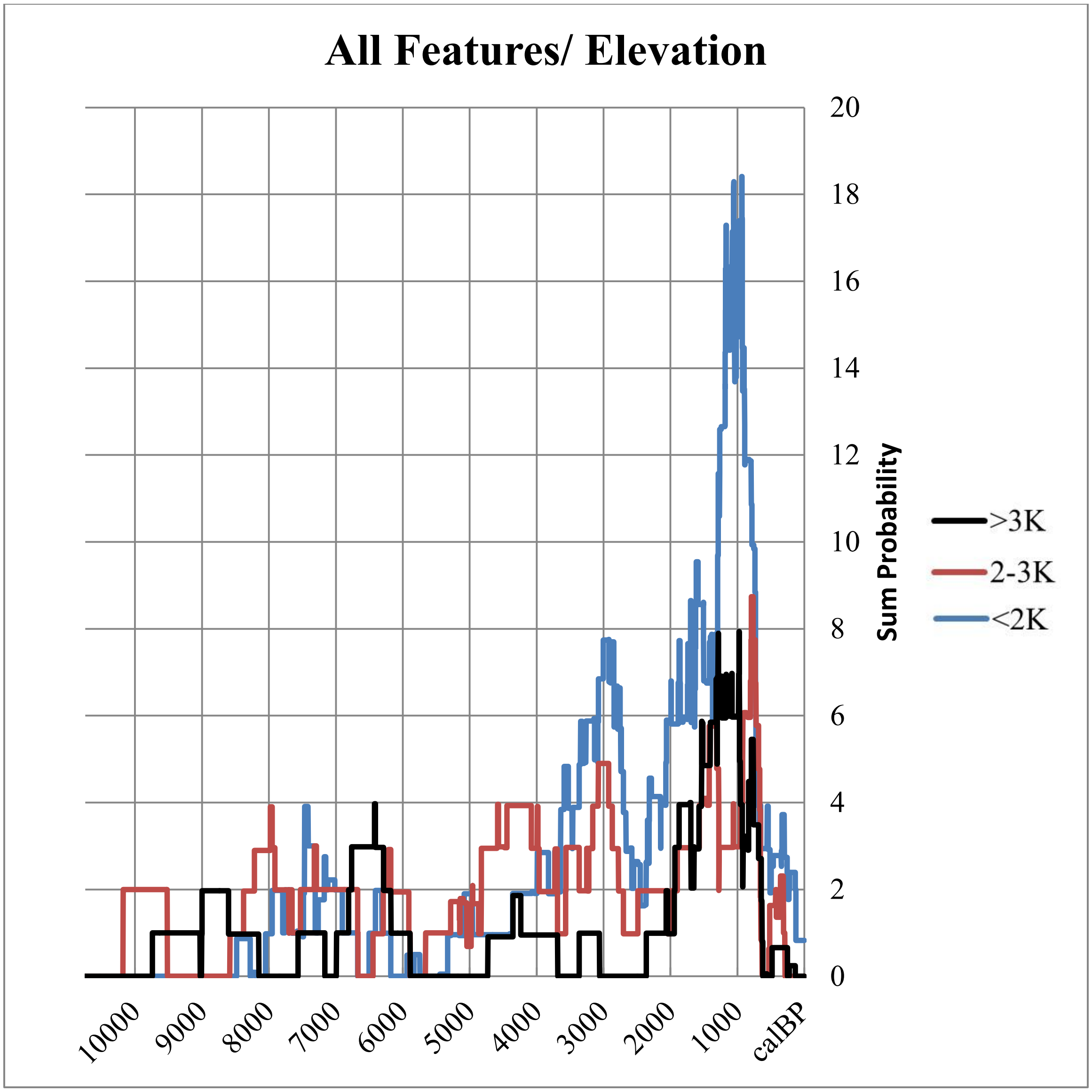

Figure 6-4: Sum probability distribution of features by elevation

Turning to unlined features specifically, Figure 6-5 details the distribution of this particular feature type by elevation. Broadly, the pattern among Paleoindian-aged unlined features remains unchanged from the aggregate feature pattern, as there are no FCR hearths older than 8050 cal BP. In the following millennia, the middle and lowest elevation ranges are best represented. Leading up to the hiatus beginning around 5800 cal BP, middle-elevation, montane areas lose representation first, followed thereafter by the plains and foothills. Notably, the highest, alpine/subalpine areas maintain the best representation and succumb to the apparent effects of the sixth millennium cal BP last. Notably, the boom in unlined hearths around 3000 cal BP is comprised almost entirely of features from the plains and foothills. Again, all feature types increase significantly around 1000 years ago.

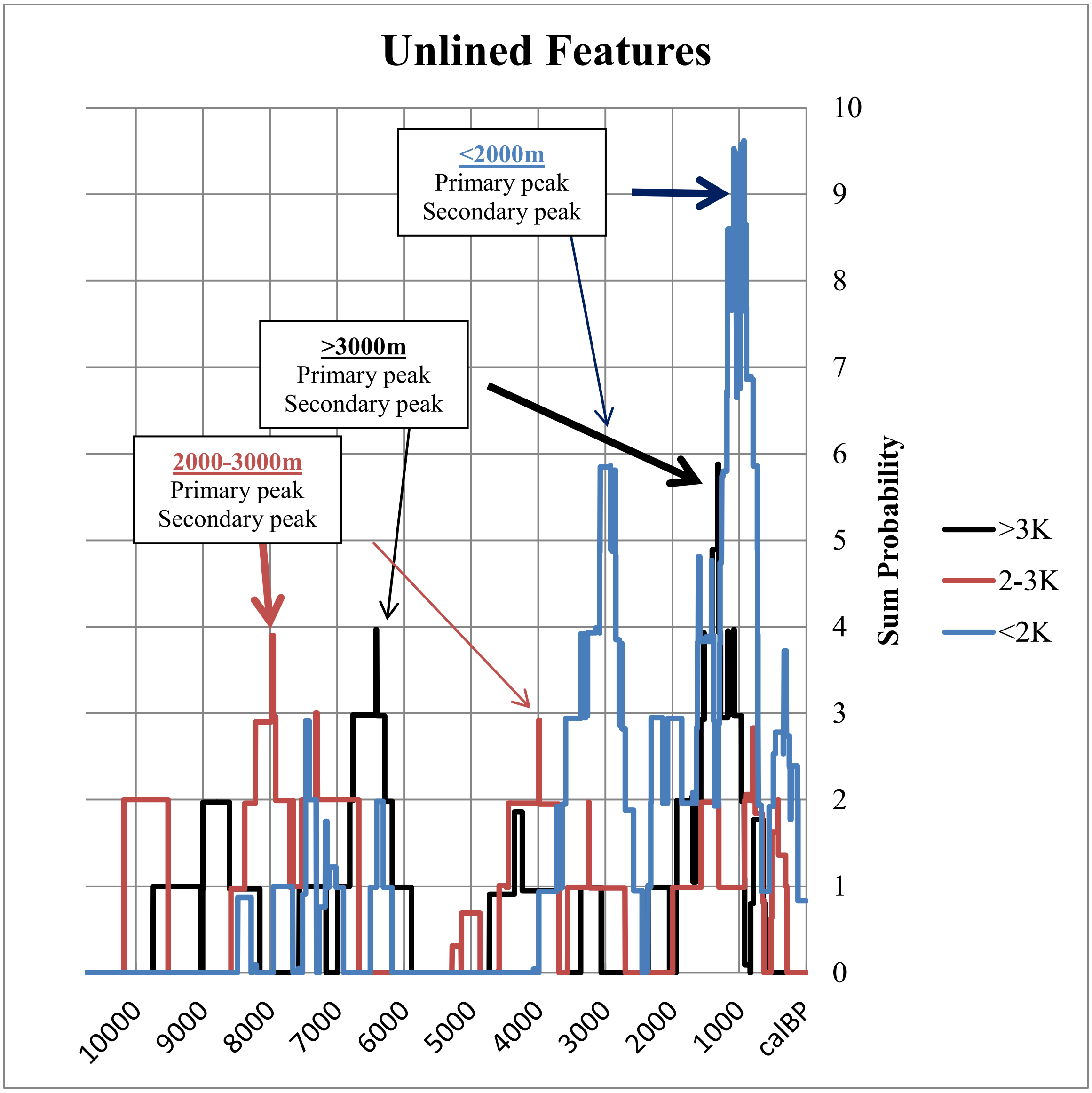

Figure 6-5: Primary and secondary peaks in sum probability distribution of features by elevation

Figure 6-5 also illustrates the broad primary and secondary peaks in thermal feature representation by elevation. The primary and secondary peaks associated with the lowest elevation are both contained within the Archaic and Late Prehistoric periods of regional prehistory, and both directly associated with the boom periods dating 1000 and 3000 years ago, respectively. In contrast, middle elevation unlined hearths are best represented at the transition between the Paleoindian and Early Archaic periods, around 8000 cal BP and secondly, during the Middle Archaic, or around 4000 cal BP. Unlined features above 3 kilometers reach their zenith, along with plains and foothills features, during the boom dated around 1000 cal BP. The secondary peak in unlined, subalpine/alpine hearths dates to around 6400 cal BP, well within the Early Archaic Period.

To summarize by cultural period, the Paleoindian Period is characterized by unlined features above 2000 m, with a near absence at elevations below 2000 m. The Early Archaic Period is initially characterized by a mixed representation of lower and middle elevations, with increasing number of hearths in higher elevations as time progresses. Just after 6000 cal BP, all feature types disappear, and the Early Archaic Period concludes with nearly no hearth signal. Unlined features gradually increase across all elevations throughout the first half of the Middle Archaic Period, after which the middle and upper elevations level off, and the lowest elevations increase to an unprecedented high. Following a brief downturn around 3000 cal BP, unlined features increase once again across all elevations to the peak around 1000 cal BP and rapidly decrease thereafter.

Turning to fire-cracked rock features (Figure 6-6), the first within the study area comes from the Willow Bunker site (5WL1656 Feature 20; Feiler 2001) appears sometime between 8052 and 7794 cal BP on the plains of eastern Weld County, at an elevation of just over 1500 meters. The second earliest FCR hearth within the study area also comes from the site 5WL1656 (Feature 1) and dates to sometime between 7762 and 7500 cal BP. Unlined features are absent thereafter until 6293 cal BP, at which time middle and lower elevation FCR hearth representation increases steadily, but remains low overall, until around 2000 years ago. The first fire-cracked rock feature above 3000 meters dates between 2064 and 1696 cal BP, almost 6000 years after its low elevation counterpart. Fire-cracked feature representation in the alpine/subalpine increases to rival the mountain zone by 1200 cal BP Around this time fire-cracked rock feature representation at the lowest elevations reaches the absolute zenith (just before 1000 calibrated years ago).

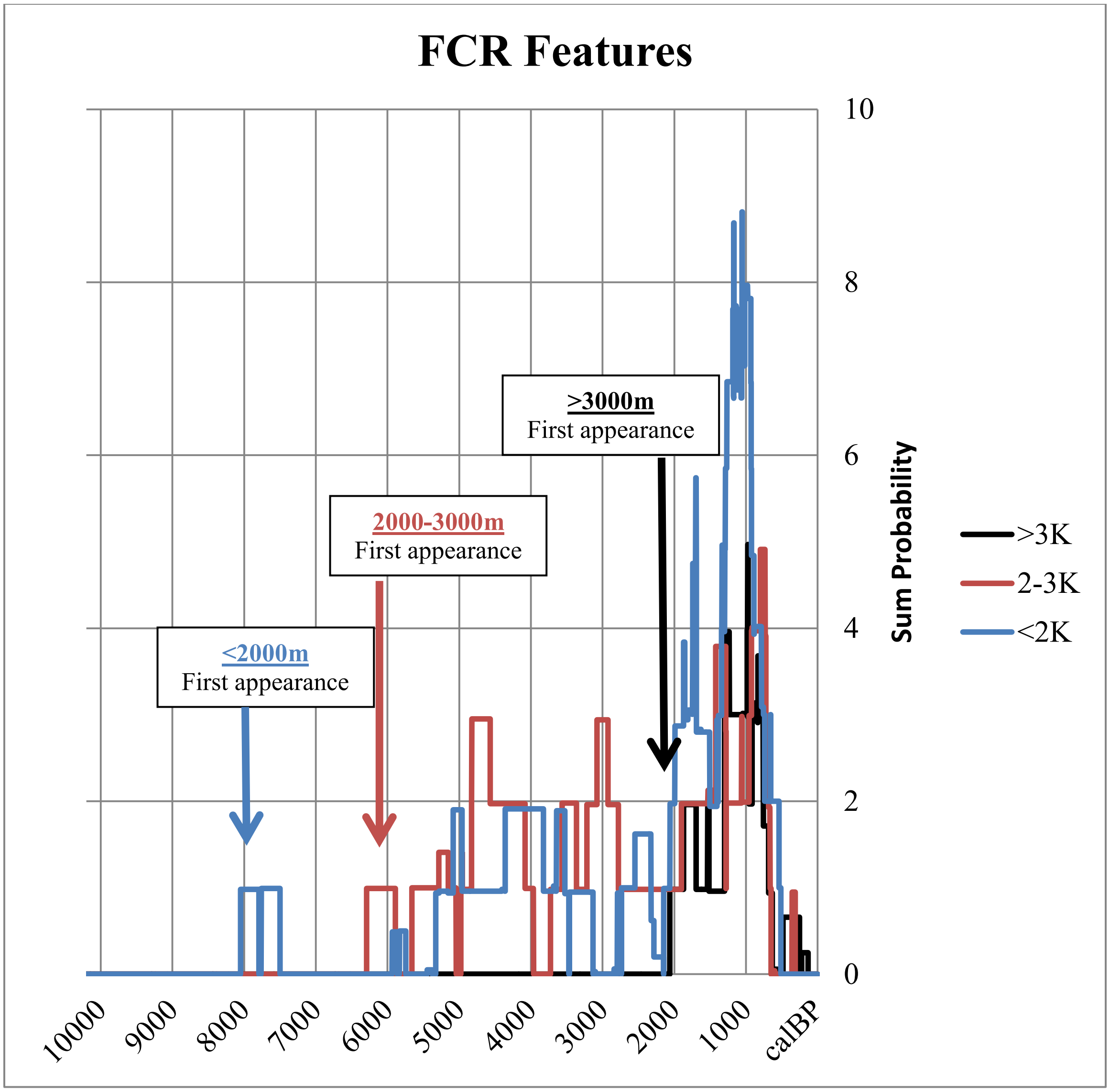

Figure 6-6: Sum probability distribution of FCR features by elevation

Thermal Feature Morphology

Table 6-3 details the mean and variance for depth and diameter measurements of the feature types under investigation in this study. Diameter here reflects the average of the length and width of a feature when those data are available. In many cases, features are discovered in profile, in which case diameter reflects a single measurement. In some cases, a profile measurement may understate the true width of a feature, depending on where the cross-section intersects the three-dimensional hearth feature. Error of this sort is almost certain and must be accepted until larger datasets are available. Similar errors in depth are also possible, but of a lesser magnitude given all features included in this study are wider than they are deep, representing basins as opposed to pits. When the inverse is true, depth errors need to be considered more closely.

Table 6-3: Depth and diameter data for the feature types under investigation

n=143	Depth (cm)			Diameter (cm)		
	Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation
Unlined	15.54	9.19	0.59	51.43	20.42	0.40
FCR	15.73	10.11	0.64	67.86	26.65	0.39
Rock-lined	25.14	9.28	0.37	52.69	26.42	0.50
All	16.07	9.72	0.61	58.09	24.60	0.42

In terms of empirical depth and variance, unlined (n=83) and fire-cracked rock hearths (n=60) are nearly identical, averaging around 15.5 centimeters with a standard deviation of around 10 cm (a coefficient of variation of around 60 percent). Rock-lined features (n=8) are generally deeper and with less variance, though it deserves mention that rock-lined hearths are sparse compared to the former feature types.

In terms of empirical diameter and variance, unlined and rock-lined hearths are nearly identical, averaging around 52 centimeters. Fire-cracked rock features are generally larger, averaging nearly 68 cm in diameter. The variances of all feature type diameters are high, between 39 and 50 percent of the mean (Table 6-3)

Table 6-4 details the results of Student’s t-test of comparisons between feature types and associated metrics. Again, the values returned from the test represent the chance of committing a type 1 error (incorrectly rejecting the null hypothesis – the null hypothesis in this case predicts no patterned relationship between feature type and size) and assuming a relationship that really does not exist. As with the Chi-squared test, the t-tests herein use a 0.05 (or 5 percent) alpha. There is not sufficient evidence to reject the null hypothesis when the test returns values greater than 0.05. Considered another way, in effect, the t-test score returns the likelihood that two samples are drawn from the same population. In terms of human behavior, t-test scores greater than 0.05 suggest that hunter-gatherers constructed hearths of various sizes independent of feature type. Turning to hearth type and morphometrics, there is not enough evidence in any direct comparisons of depth and diameter detailed above to reject the null hypothesis and recognize a patterned relationship between size and type. When comparing the relationship between depth and diameter together, expressed as a depth to diameter ratio, FCR hearths and unlined features narrowly elude statistical significance. Prehistoric Northern Colorado residents constructed hearths of various sizes independent of feature type.

Table 6-5 details differences in feature type, morphometrics, and radiocarbon age. The data are principally arrayed by feature type and subsequently by cultural period. Again, the data are characterized by extraordinary variance. Unlined feature depth varies by as much as 75 percent and as little as 53 percent of the mean; diameter varies by as much as 56 percent and as little as 28 percent of the mean. Notably, the greatest variance is within the oldest cultural period, and may be a function of human behavior or the aggregate taphonomic effects bearing on deposits of such antiquity. Given the above data, it is impossible to demonstrate differences in feature type and constructed feature size through time and across cultural periods. Prehistoric

Northern Colorado residents constructed hearths of various sizes independent of feature type, and independent of time.

Table 6-4: Statistical comparison of feature metrics - red cells indicate low scores

T test	Depth		
	Unlined	**FCR**	**Rock-lined**
Unlined	X	X	X
FCR	0.08	X	X
Rock-lined	0.65	0.24	X
T test	**Diameter**		
	Unlined	**FCR**	**Rock-lined**
Unlined	X	X	X
FCR	0.28	X	X
Rock-lined	0.29	0.13	X
T test	**Depth/Diameter**		
	Unlined	**FCR**	**Rock-lined**
Unlined	X	X	X
FCR	0.05	X	X
Rock-lined	0.57	0.66	X

The hearth data set can be further differentiated by elevation. Table 6-6Figure 6-6 and Table 6-7 detail the average diameter and depth respectively for the various hearth types and the elevation ranges under study. When viewed this way, a few interesting points emerge. First, with regard to unlined and fire-cracked rock features, there is a general trend towards the greatest number of features at the lowest elevations. Moreover, all unlined features are approximately the same size, varying around 50 cm in diameter, and the largest unlined features generally occur between two and three thousand meters with the exception of the Paleoindian Period. Though the sample size is low, the largest Paleoindian features occur above 3000 meters. On the other hand, fire-cracked rock features vary much more widely and tend to be much larger at the lowest elevations. When evaluated statistically, again using the Student t-test, patterns in unlined feature diameter do not demonstrate significant differences (Table 6-8). The diameter of unlined features across cultural periods and elevations is effectively equal. On the other hand, depth comparisons between middle and low elevation Archaic Period unlined hearths (n = 22.64; n = 15.09) and between Late Prehistoric hearths above and below 3000 meters (n = 9.85; n = 17.67, 17.35) do demonstrate strong patterned differences in depth. The data suggest features at lower elevations were generally deeper that ones at higher elevations, though Archaic-era features do not follow this pattern, and are generally deeper between 2000 and 3000 meters, than they are at elevations below 2000 meters (Table 6-8).

Table 6-5: Comparison of patterns in feature metrics by type and age

n=143		**Depth (cm)**			**Diameter (cm)**		
		Mean	**Standard Deviation**	**Coefficient of Variation**	**Mean**	**Standard Deviation**	**Coefficient of Variation**
Unlined	Paleoindian (n=7)	14.93	11.24	0.75	43.71	24.30	0.56
	Archaic (n=42)	170.05	9.06	0.53	53.64	23.85	0.44
	Late Prehistoric (n=34)	13.94	8.90	0.64	50.29	14.19	0.28
FCR	Paleoindian (n=0)	-	-	-	-	-	-
	Archaic (n=20)	19.71	13.82	0.70	62.26	22.55	0.36
	Late Prehistoric (n=40)	15.76	8.44	0.54	65.85	25.63	0.39

Table 6-6: Comparison of feature diameter by type, elevation, and age

Mean Diameter			
Unlined (n=83)	**Paleoindian (n=7)**	**Archaic (n=42)**	**Late Prehistoric (n=34)**
>3000m (n=19)	52.83 (n=3)	45.88 (n=8)	48.88 (n=8)
2000-3000m (n=19)	36.88 (n=4)	59.14 (n=11)	53.79 (n=7)
<2000m (n=42)	-	53.72 (n=23)	49.61 (n=19)
FCR (n=60)	**Paleoindian (n=0)**	**Archaic (n=20)**	**Late Prehistoric (n=40)**
>3000m (n=11)	-	43.00 (n=1)	49.60 (n=10)
2000-3000 m (n=19)	-	55.07 (n=7)	79.75 (n=12)
<2000m (n=31)	-	67.21 (n=12)	73.83 (n=18)

Fire-cracked rock hearths show a similar trend in the Late Prehistoric period (Archaic Period comparisons are limited by a low sample size above 3 thousand meters; Table 6-6 and Table 6-7). Specifically, features above 3000 m differ statistically (in terms of depth and diameter) from features native to the 2-3 thousand meter range, as well as below 2 thousand meters. On the other hand, the lowest and middle elevations do not differ statistically in terms of either depth or diameter from one another (Table 6-9). Thus, it appears that while unlined feature depth differs, variably, between various elevation ranges, there is a clear pattern towards wider and deeper fire-cracked rock features at lower elevations, and smaller and shallower features above 3 thousand meters.

Table 6-7: Comparison of feature depth by type, elevation, and age

Mean Depth			
Unlined (n=78)	**Paleoindian (n=7)**	**Archaic (n=39)**	**Late Prehistoric (n=32)**
>3000m (n=19)	9.17 (n=3)	14.00 (n=7)	8.25 (n=7)
2000-3000m (n=19)	13.5 (n=4)	22.64 (n=10)	14.36 (n=6)
<2000m (n=42)	-	15.09 (n=22)	17.13 (n=19)
FCR (n=59)	**Paleoindian (n=0)**	**Archaic (n=20)**	**Late Prehistoric (n=39)**
>3000m (n=11)	-	7.00 (n=1)	9.85 (n=10)
2000-3000m (n=19)	-	13.00 (n=7)	17.67 (n=12)
<2000m (n=31)	-	15.33 (n=12)	17.35 (n=17)

Table 6-8: T-test results of metric comparisons between unlined feature age and elevation - red cells indicate low scores

Unlined T-test Depth				**Unlined T-test Diameter**			
	Paleoindian				**Paleoindian**		
	>3000m	2000-3000 m	<2000m		>3000m	2000-3000 m	<2000m
>3000m	X	X	X	>3000m	X	X	X
2000-3000 m	0.59	X	X	2000-3000 m	0.51	X	X
<2000m	-	-	X	<2000m	-	-	X
	Archaic				**Archaic**		
	>3000m	2000-3000 m	<2000m		>3000m	2000-3000 m	<2000m
>3000m	X	X	X	>3000m	X	X	X
2000-3000 m	0.07	X	X	2000-3000 m	0.61	X	X
<2000m	0.68	**0.01**	X	<2000m	0.21	0.97	X
	Late Prehistoric				**Late Prehistoric**		
	>3000m	2000-3000 m	<2000m		>3000m	2000-3000 m	<2000m
>3000m	X	X	X	>3000m	X	X	X
2000-3000 m	**0.04**	X	X	2000-3000 m	0.58	X	X
<2000m	**0.03**	0.69	X	<2000m	0.86	0.38	X

Table 6-9: T-test results of metric comparisons between FCR feature age and elevation - red cells indicate low scores

FCR T-test Depth				FCR T-test Diameter			
	Archaic				Archaic		
	>3000m	2000-3000 m	<2000m		>3000m	2000-3000 m	<2000m
>3000m	X	X	X	>3000m	X	X	X
2000-3000 m	-	X	X	2000-3000 m	-	X	X
<2000m	-	0.60	X	<2000m	-	0.14	X
	Late Prehistoric				Late Prehistoric		
	>3000m	2000-3000 m	<2000m		>3000m	2000-3000 m	<2000m
>3000m	X	X	X	>3000m	X	X	X
2000-3000 m	**0.01**	X	X	2000-3000 m	**0.01**	X	X
<2000m	**0.03**	0.88	X	<2000m	**0.01**	0.87	X

In conclusion, the preceding chapter presents the spatiotemporal and morphological data drawn from the synthesis of previously excavated hearth features as well as the original data generated as a result of the efforts of the 2009, 2010, and 2011 archaeological field schools. Broadly, the data suggest there are differences in the way individual hearth features are distributed across different elevation ranges, and through time, and there are a few differences in the size of some features across time and space. More to the point, the distribution of unlined and FCR features through time and space differs in meaningful ways (discussed in more detail in Chapter 8), and while there is not enough evidence in any direct comparisons of depth and diameter to reject the null hypothesis and recognize a patterned relationship between size and feature type, when considering individual feature types, the data suggest features at lower elevations were generally deeper that ones at higher elevations, and may suggest taphonomic influence, or perhaps may reflect social and individual behavioral differences in feature use.

CHAPTER 7 THE MACROBOTANICAL RECORD

The following chapter discusses the macrobotanical and fuel wood data used in the present study. In short, this chapter raises many more questions than it answers. The macrobotanical record of Northern Colorado is very thin. In fact, only 17 of 193 recorded features (8.8 percent) have macrobotanical data and only 44 of 193 (22.8 percent) have associated fuel wood data. The realization of how truly limited this line of evidence is, despite the popularity and ease of macrobotanical flotation, is perhaps the most surprising and thought-provoking result of this investigation. The interested reader is directed to Appendix D, which details some non-hearth macrobotanical sources for comparison.

Fuel Wood Data

Table 7-1 details the recovered fuel samples identified in this study. Ten of the forty-four features contained evidence of more than one fuel type. It is unclear if different fuels represent separate, time-differentiated firings, a single (or near synchronous) event with multiple fuel sources, or sampling error. More fuel and associated chronological data are necessary to address such questions in more detail.

Figure 7-1 illustrates the frequency distribution of identified fuel sources. The most frequent identified fuel wood charcoal is mountain mahogany. Cercocarpus is group of small, deciduous shrubs native to semi-desert habitats of the western United States and particularly the Southern Rocky Mountains (USDA Plants Database). Elsewhere, members of the Cercocarpus genus grow up to 5 meters. Cercocarpus montanus rarely reaches this size, as it is a favorite of browsers such as deer and elk, particularly at higher elevations. Saltbush, and/or greasewood make up the second most frequent fuel type (the two are separate species, but differentiating between the two, as charcoal, is often very difficult). Saltbush (Atriplex) is a widely distributed plant genus comprised of drought tolerant shrubs growing up to a meter in height. Saltbush is very salt tolerant, and thrives in salty, alkaline soils associated with arid and semi-arid environments (USDA Plants Database). Greasewood (Sacrobatus) is a deciduous, drought-tolerant shrub native to the semi-arid and arid regions of the western United States. This short-growing shrub is also often found in extremely dry and saline environments, such as arroyos and dry streambeds (USDA Plants Database). Juniperus (Juniper), a common, semi-arid native conifer and member of the cypress family is also well represented.

Table 7-1: Common and botanical names of charcoal samples identified by this study – see Appendix A for site references

Site	Feature ID	Identified Charcoal Materials	
		Common name	Botanical name
5BL70	A	Fir	*Abies sp.*
		Spruce	*Picea sp.*
5BL94	A	Conifer	*Coniferae sp.*
		Willow	*Salix sp.*
5BL153	1	Fir	*Abies*
		Spruce	*Picea sp.*
		Conifer	*Coniferae sp.*
	2	Fir	*Abies*
		Spruce	*Picea sp.*
		Conifer	*Coniferae sp.*
	3	Spruce	*Picea sp.*
	4	Spruce	*Picea sp.*
		Fir	*Abies*
	6	Fir	*Abies*
		Spruce	*Picea sp.*
5BL3440	1	Subalpine Fir	*Abies lasiocarpa*
5BL4838	1	Pine sp.	*Pinus sp.*
	2	Pine sp.	*Pinus sp.*
5BL10853	1	(Aspen or Cottonwood)/Willow	*Populus sp. or Salix sp.*
	3	(Aspen or Cottonwood)/Willow	*Populus sp. or Salix sp.*
5GA22	A4	Subalpine Fir	*Abies lasiocarpa*

Site	Feature ID	Identified Charcoal Materials	
		Common name	**Botanical name**
5GA2524	1	Juniper	*Juniperus sp.*
5LR13	3	Pine sp.	*Pinus sp.*
5LR104	1	Piñon pine	*Pinus edulis*
		Juniper	*Juniperus sp.*
	11	Piñon pine	*Pinus edulis*
		Juniper	*Juniperus sp.*
	18	Juniper	*Juniperus sp.*
		Ponderosa Pine	*Pinus ponderosa*
5LR161	14	Juniper	*Juniperus sp.*
5LR252	2	Mountain mahogany	*Cercocarpus montanus*
	5	Mountain mahogany	*Cercocarpus montanus*
	6	Mountain mahogany	*Cercocarpus montanus*
	7	Mountain mahogany	*Cercocarpus montanus*
	8	Mountain mahogany	*Cercocarpus montanus*
	10	Mountain mahogany	*Cercocarpus montanus*
	18	Mountain mahogany	*Cercocarpus montanus*
	21	Mountain mahogany	*Cercocarpus montanus*
	29	Mountain mahogany	*Cercocarpus montanus*
	33	Mountain mahogany	*Cercocarpus montanus*
	44	Mountain mahogany	*Cercocarpus montanus*
	10a	Mountain mahogany	*Cercocarpus montanus*
5LR1370	2	Conifer	*Coniferae sp.*
	3	Doug Fir	*Pseudotsuga menziesii*
		Ponderosa Pine	*Pinus contorta*
5LR9991	11	Saltbush or Greasewood	*Atriplex sp. or Sacrobatus sp.*
	12	Saltbush	*Atriplex sp.*
	13	Saltbush	*Atriplex sp.*
		Greasewood	*Sacrobatus sp.*
5LR11585	TF1-1	Ponderosa Pine	*Pinus ponderosa*
	TF2-1	Ponderosa Pine	*Pinus ponderosa*
	TF-3-3	Juniper	*Juniperus sp.*
5LR11711	TF-4	Saltbush or Greasewood	*Atriplex sp. or Sacrobatus sp.*
5LR11718	6	Saltbush or Greasewood	*Atriplex sp. or Sacrobatus sp.*
	16	Pine	*Pinus sp.*
5LR11836	1	Saltbush, Boxelder, Pine	*Atriplex sp., Acer negundo, Pinus sp.*
5WL1794	8	Conifer	*Coniferae sp.*

Site	**Feature ID**	**Identified Charcoal Materials**	
		Common name	**Botanical name**
S10-2	1	Saltbush	*Atriplex sp.*
		Greasewood	*Sacrobatus sp.*

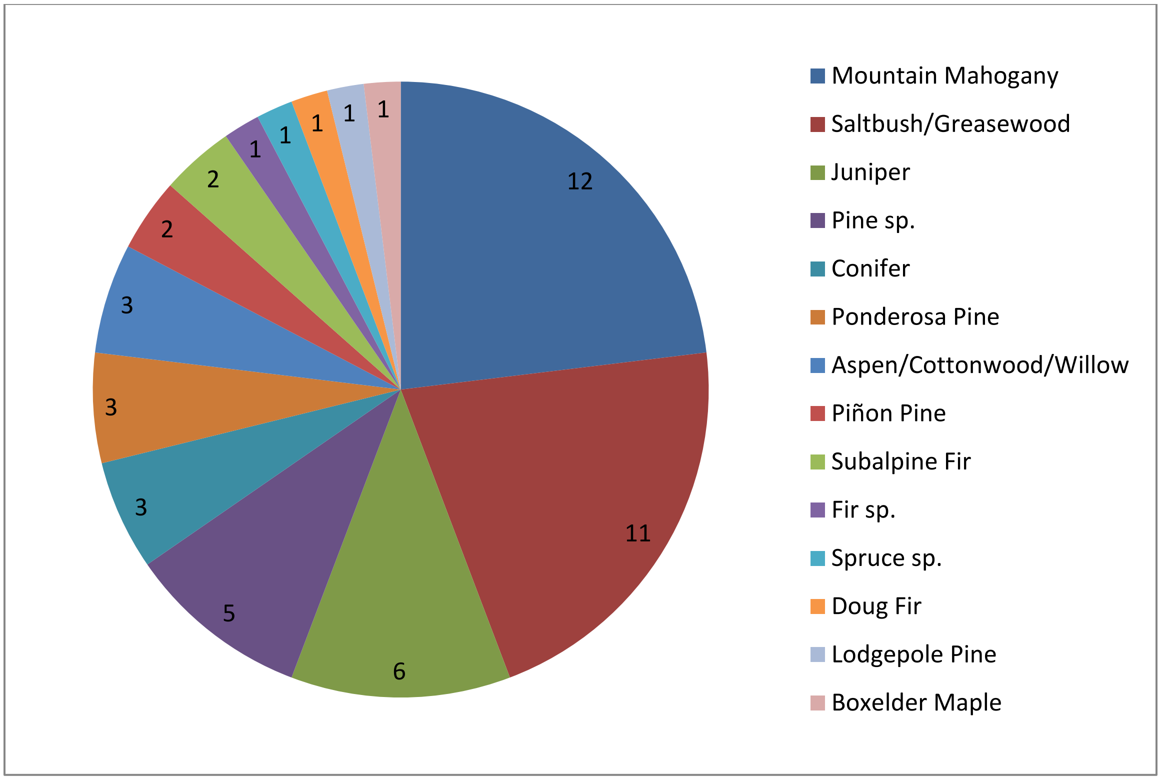

Figure 7-1: Frequency of identified charcoal sample species

Macrobotanical Data

Table 7-2 lists the 26 identified macrofloral samples, recovered from 17 hearths across the study area. One of the recovered samples was identified as root type materials, and one sample was identified as charred, non-diagnostic parenchymous tissue; the remaining 24 were charred seeds. Feature 2 from site 5GA151 contained evidence of both charred seeds and charred root material, and is a large unlined hearth dating between 1309 and 1571 cal BP. Amongst the more frequently identified seeds, Goosefoot (Chenopodium sp.) has a long history of use by humans, likely due to its preference for disturbed soils, including abandoned campsites. Assuming some site-reuse strategies, early and prolonged human/goosefoot interaction is a certainty. In fact, evidence of extensive cultivation by humans dates back over 3400 years cal BP in the eastern woodlands of North America (Smith and Cowan 1987). The only remaining identifiable source of charred seeds in thermal features is a variety of wild grasses, namely of the genus festuca and/or the broader family poaceae; poaceae accounts for over 230 genera and over 1000 domestic and wild species in North America (USDA Plants Database), and includes all the cereal grains. The representation of grasses in thermal features may be a factor of the ubiquitous distribution and density of these types of plants (compare to the roughly 150 species of chenopodium), or their visibility in the archaeological record may also suggest the use of grasses as fuel.

Table 7-2: Common and botanical names of macrobotanical samples used in this study – see Appendix A for site references

Site	Feature ID	Identified Macrobotanical Materials	
		Common name	Scientific name
5BL153	2	Strawberry	Fragaria
		Juniper fruit tissue	Juniperus
	4	Goosefoot	Chenopodium
		Grasses	Poaceae
		Bistort	Polygonum
5GA869	II-N-A	Goosefoot	Chenopodium
		Prickly Poppy	Argemone
5LR161	14	Goosefoot	Chenopodium
5LR1370	3	Legume	Fabaceae
		Kinnikinnick	Arctostaphylos Uva-Ursi
5LR9991	1	Indian Rice Grass	Oryzopsis hymenoides
5LR11836	1	Stem or root part	Burned parenchymous tissue
5WL1483	1	Goosefoot	Chenopodium
	2	Goosefoot	Chenopodium
		Sunflower	Helianthus sp.
	4	Goosefoot	Chenopodium
	6	Goosefoot	Chenopodium
5WL1555	9	Goosefoot	Chenopodium
5WL1794	8	Saltwort	Salsola

Site	Feature ID	Identified Macrobotanical Materials	
		Common name	**Scientific name**
5WL2382	7	Goosefoot	Chenopodium
		Wild licorice	Glycyrrhiza
		Spiny cocklebur	Acanthoxanthium
5WL2383	16	Unidentified seed	
	17	Unidentified Seed	
5WL4088	1	Grasses	Festuca
		Grasses	Poaceae

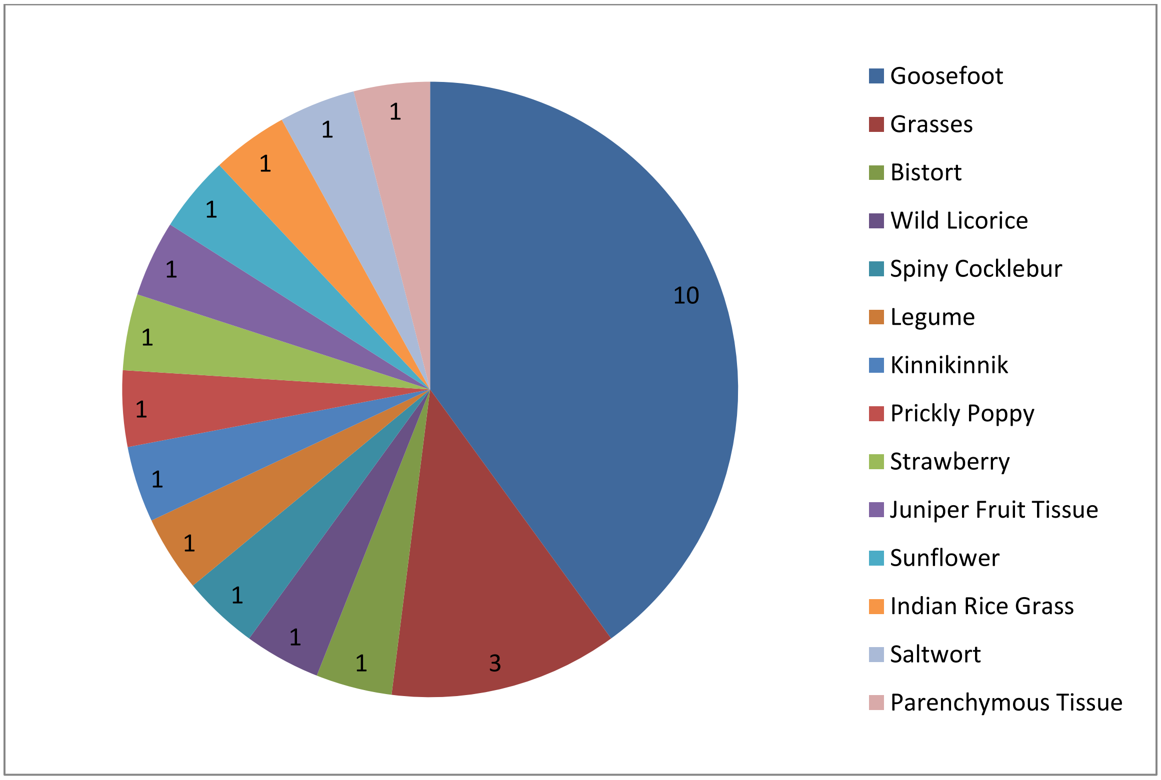

Figure 7-2: Frequency of identified macrobotanical material species

Summary

Table 7-3 details the percentage of features with associated macrobotanical and fuel wood data. First, more hearths have returned identified charred wood samples than other, more direct-subsistence related macrobotanical data. Second, the trends within each data type are directly inverted from one another. That is, the greatest number of features with associated macrobotanical data are unlined, FCR, and rock-lined, in that order. Alternatively, the greatest number of features with associated fuel wood data is the exact opposite: rock-lined, FCR, and unlined, in that order. This is counter intuitive; all else-being equal, one would expect features that favor preservation of wood, to also favor preservation of other types of plant remains. There may be hitherto unidentified differences in the application and/or success of the methods, but the available data suggest that the distribution of material within feature types is at least partially influenced by human behavior. Lastly, while the limited sample size of rock-lined features may skew interpretation, there is a strong difference in the number of rock-lined features with fuel wood and other macrobotanical data. Moreover, while the difference in fuel and macrobotanical representation of unlined and FCR features are not as great, these data sets are more robust. There are nearly twice as many unlined hearths with identifiable macrobotanical remains than FCR features. Alternatively, there are nearly twice as many FCR hearths with identified fuel wood than unlined features. Again, it is reasonable to expect features that favor preservation of wood, to also favor preservation of other types of plant remains and visa-versa. Thus, until more data are available, it appears that in general, unlined features contained and potentially processed more seeds than FCR hearths.

Table 7-3: Percentage of hearths types with associated fuel wood and macrobotanical data

Feature Type	Count	Percent Macrobotanical ID	Percent Fuel ID
Unlined	99	12.12	16.16
FCR	73	6.94	33.33
Rock-lined	9	0.00	33.33
All	180	9.94	23.89

Table 7-4 and Table 7-5 illustrate the differences in recovered macrofloral and fuel wood materials through time and across elevation ranges; the results are not surprising. First, there is a general trend towards greater representation of macrofloral materials in hearths dating to the most recent past and decreasing progressively as one proceeds through the earlier cultural periods. Moreover, there are more identified materials associated with elevations less than 2000 meters than any other elevation. Interestingly, the pattern does not continue uphill. Specifically, elevations over 3000 meters show at least as many macrofloral remains and over twice as many features with identifiable fuel source as the 2-3 thousand meter range. The strong representation of macrofloral remains at the highest elevations may be a result of increased usage of seeds at that elevation (which is unlikely given the shorter window of fruition for these types of plants relative to lower elevations), differences in preservation (which is a possibility), or differences in research extent and quality (likely). Specifically, the work of the late James Benedict comes to mind (1973, 1979, 1981, 1985, 1991, 1993, 1996, 1998, 2000, and 2005). In fact, every feature occurring over 2400 m with associated fuel and/or macrobotanical data (and most every feature with 14C dates for that matter) derives specifically from Benedict's work in the high country on the Indian Peaks Wilderness. His attention to detail and thorough methodologies and analysis are unparalleled and certainly contributed to the strong representation of the high country.

Table 7-4: Percentage of hearths with fuel wood and macrobotanical data by age

Stage	Count	Macrobotanical ID	Fuel ID
Paleoindian	10	0.00	10.00
Archaic	67	5.97	31.34
Late Prehistoric	103	13.59	25.24
All	180	9.44	23.89

Table 7-5: Percentage of hearths with fuel wood and macrobotanical data by elevation

Elevation	Count	Macrobotanical ID	Fuel ID
>3000m	37	5.41	24.32
2000-3000m	44	4.55	13.63
<2000m	99	14.14	32.32
All	180	9.44	23.89

In conclusion, the preceding chapter discusses the macrobotanical and fuel wood data used in the present study. In short, this chapter raises many more questions than it answers. The macrobotanical record of Northern Colorado is very thin; only 17 of 193 recorded features (8.3 percent) have macrobotanical data and only 44 of 193 (22.3 percent) have associated fuel wood data. Forty-four features contained identifiable fuel wood, and ten of the forty-four features contained evidence of more than one fuel type; the most frequent identified fuel wood charcoal is mountain mahogany. Macrobotanical data was recovered and identified from 17 hearths across the study area, representing 14 individual species. One of the recovered samples (n=26), one was identified as root type materials, and one as burned parenchymous tissue (root or stem part); the remaining 24 were charred seeds. There are nearly twice as many unlined hearths with identifiable macrobotanical remains than FCR features. Alternatively, there are nearly twice as many FCR hearths with identified fuel wood than unlined features. There is a general trend towards greater representation of macrofloral materials in hearths dating to the most recent past and decreasing progressively as one proceeds through the earlier cultural periods. Additionally, there are more identified materials associated with elevations less than 2000 meters than any other elevation, though the pattern does not continue uphill (elevations over 3000 meters show at least as many macrofloral remains and over twice as many features with an identifiable fuel source as the 2-3 thousand meter range).

In the absence of plant remains useful for addressing questions of feature content differences between feature types, time, and elevation in more detail, the factors contributing to the near paucity of macrobotanical data necessarily becomes the point of inquiry. To this end, I have identified a few known factors contributing to these remarkably low numbers, but there are also possible taphonomic and human behavioral influences that need consideration. Foremost among these, macrobotanical analysis generally does not result in firm species identification and has an overall low rate of return. There are a few possible issues at play. First, it may be that many of the charred remains recovered from hearths cannot be identified. While this is certainly true in some cases, there are few examples of recovered plant remains that cannot be identified, at least on some level; there are only three instances of completely unidentifiable charred seeds in this study (3 of 17; approximately 17 percent). Alternatively, there may be little-to-no recovered plant materials in hearth features because those materials were not processed within them. The paucity of material may also indicate unfavorable preservation conditions within the study area. Soil type, clay and moisture content, pH and chemical composition, and other local conditions all effect macrofloral preservation and recovery via the flotation method (0). The near absence of macrofloral data in association with hearths in Northern Colorado is likely a result of a combination of the above factors. There is not, at present, enough evidence to address this issue in more detail, though the interested reader is referred to Pearsall (2000), Wagner (1982), Wright (2005), and Vandorpe and Jancomet (2007) for more information.

CHAPTER 8 DISCUSSION

One of the fundamental issues driving this research is the fact that variation in thermal feature design has largely been ignored in northern Colorado. Elsewhere, however, formal thermal feature variation has been the subject of some specific inquiries, and broad hypothesis for the form, function, and evolutionary tendencies of features have been proposed. The following highlights some of the more salient studies on the topic, and incorporates insights drawn from patterns within the present data set.

When considering feature variation at a very broad scale, Thoms (2001) argued that as population density increased, people were pressured to develop new strategies to extract a greater food resource potential from a given landscape, largely by intensifying previously unused or underused resources. This is principally manifest as changes in cooking strategies, and specifically as an increasing use of cook stones in thermal feature design in order to access low ranked plant foods. Cook stones act as passive heat receptacles, and once thoroughly heated, can radiate heat energy for an extended period and create long-term, high-heat conditions. The same cooking principle continues to be used to this day in modern ovens, and certainly was practiced in a more traditional fashion in the recent ethnographic past.

Wandsnider (1997) illustrates the relationship between cooking strategies and the complex carbohydrate content (particularly inulin and fructan) of many plant food-resources. She draws a distinction between protein denaturation, i.e. meat cooking- which requires relatively little thermal energy- and the comparatively costly process of carbohydrate hydrolysis (Figure 8-1) Hydrolysis refers to the process of cleaving chemical (glycosidic) bonds using a water molecule and heat energy. She argues that the consumption of geophytic plant foods (roots, tubers, rhizomes) necessitated prolonged, medium-to-high heat processing strategies manifest in the design of rock-filled “earth ovens” and other heat-retaining thermal features. That is, the inclusion of a heating element designed to produce long-term heating conditions is a direct response to the biochemical characteristics and associated processing requirements of particular plant foods that are utilized, to varying degrees, by humans at particular points throughout the past (Wandsnider 1997: 28-29). She demonstrates that the connection between plant food processing and the inclusion of rock in feature design is more than a functional interpretation and, in fact, is borne out by the ethnographic literature. Of 89 ethnographic examples of pit hearth cooking, 80 percent were used to process plants exclusively and 80 percent of those utilized rock as a heating element. Additionally, of the 12 examples of pit hearth processing of animal foods, only three included rocks, and of the five examples of mixed plant and animal processing, rock was always used (1997: 20-21).

Following the arguments outlined by Wandsnider and Thoms, and with regard to data presented in the preceding chapters, I argue that changes in northern Colorado thermal feature morphology coevolve with the increasing use of lower-ranked plant foods in an effort to extract a greater amount of the food-resource potential from a given landscape. The inclusion of rock as a heating element in hearth design signals changing landscape-use strategies aimed at offsetting the shortfalls of decreasing availability of high ranked resources and making available, in their stead, a broad range of lower-ranked, more processing-intensive foods. The appearance of these rock-inclusive feature types serves as a proxy for monitoring increasing dietary breadth in the archaeological record, and periods with greater representation of FCR features relative to other feature types indicate periods of greater reliance on low-order plant foods (Figure 8-2). Furthermore, I propose that the general implications of Optimal Foraging theory and the dietary breadth hypothesis (Bettinger 1987; Bettinger 2009; Smith 1983; Smith and Winterhalder 1985;

Winterhalder 1980; Winterhalder 1983; Winterhalder 1986; Winterhalder 2001; Winterhalder and Kennett 2009; Winterhalder and Smith 2000) provide the theoretical basis for expected changes in subsistence strategies and cooking technology, and provide a robust explanation for the evolution of thermal feature morphology in northern Colorado.

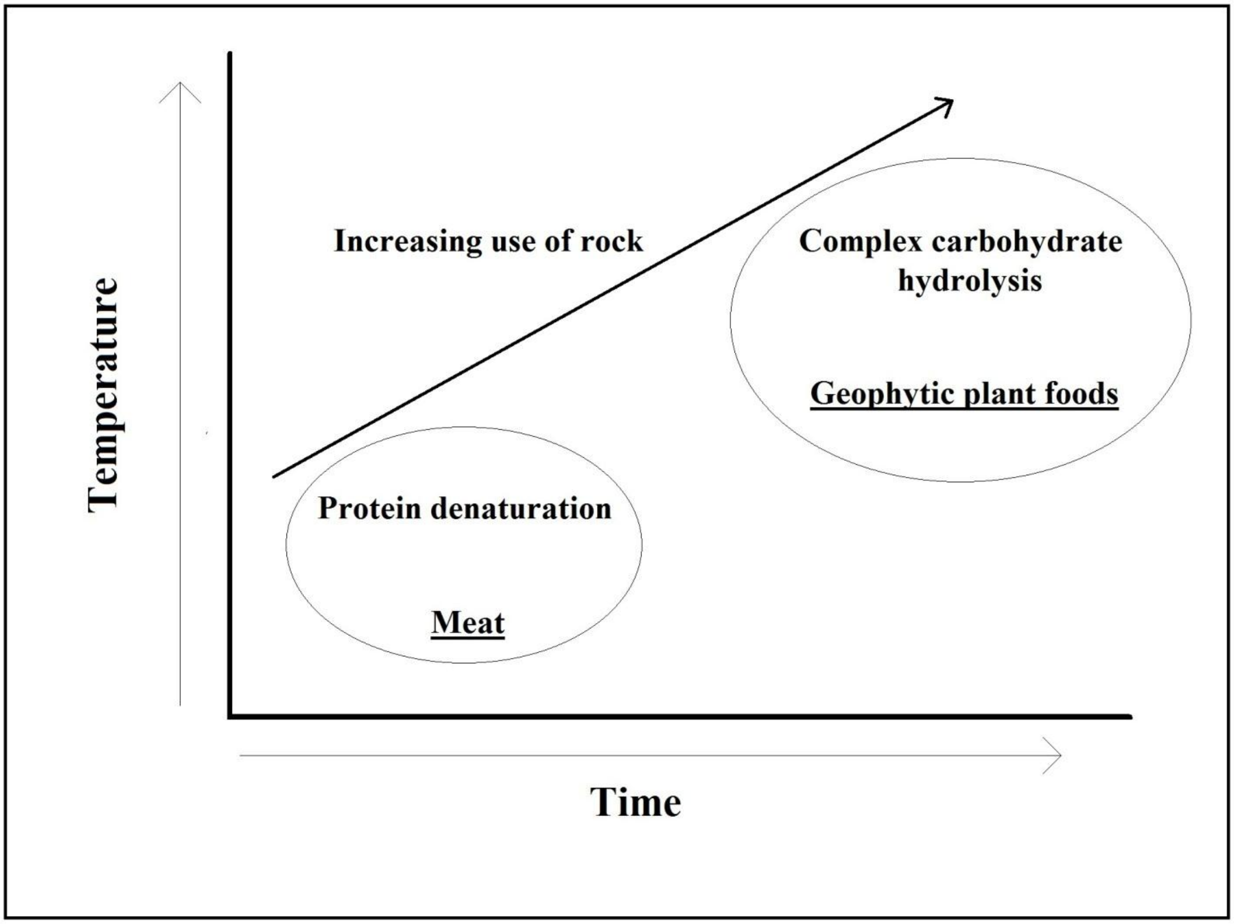

Figure 8-1: Generalized biochemical characteristics and processing requirements of plant and animal foods (adapted from Wandsnider 1997)

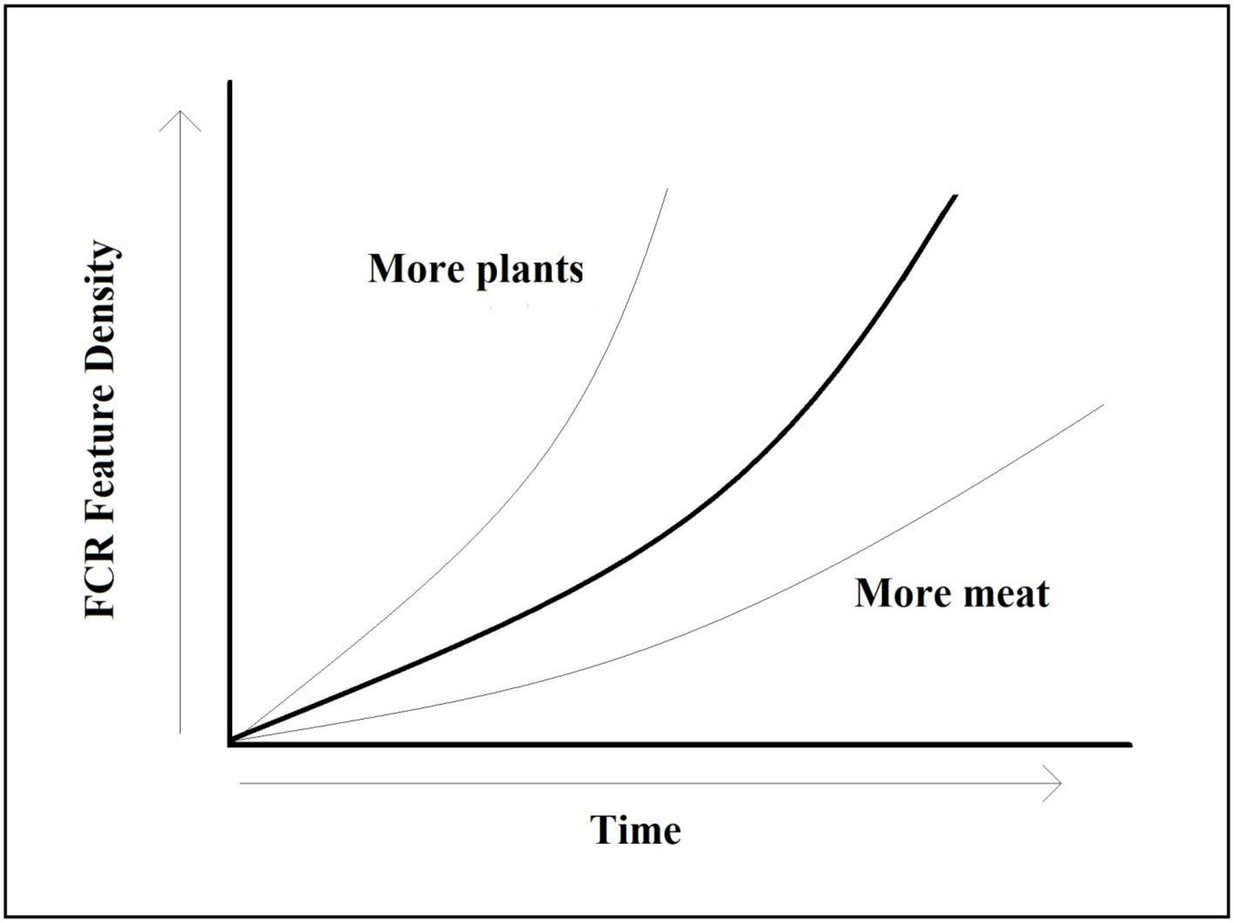

Figure 8-2: Model of FCR feature use-intensity, adapted from Thoms 2009

Specifically, Optimization theory is the belief that, in aggregate, humans will pursue behaviors that maximize their gains or rewards, while simultaneously minimize the associated costs. In other words, human behavior (particularly subsistence behavior, as it has been traditionally applied) should tend towards efficiency over time[1]. The logic of optimization-based theories is based in selectionist evolution (Kelly 1995). Traditional selectionist evolutionary theory hypothesizes that if a genotype is heritable and has direct implications on fitness[2], it can

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[1] It is important to note that it is not assumed that all behavior is optimal, simply that in aggregate, behavior *tends* towards optimization; this is sometimes referred to as constrained optimization (Winterhalder and Kennett 2006).

[2] Fitness refers to the ability to both survive and reproduce. In order to increase in frequency through time, and thus become recognizable, the genotype or trait in question must constitute an advantageous adaptation to a set of

be selected for and may, under specific circumstances, increase in frequency through time[3]. Optimization theory postulates that human behavior and decision-making can be conceived of as phenotypes (the expressed extension of the genotype) that can be inherited, somewhat variably expressed, selected for, and passed on. While few would doubt that optimizing behaviors aimed at maximizing returns and minimizing costs would have clear and direct implications of fitness, heritability of behavior (particularly complex human behavior) is less clear. The relationship between behavior and inheritance has been explored from a multitude of angles, and perhaps most notably as the central point in the 'nature vs., nurture' debate, the sociobiological thesis, and sociobiology more broadly. Many proponents of an optimization-based approach to human behavior argue that while specific behaviors may not be *genetically* selected for, behaviors that are linked to increased fitness within a specific context can be passed down through cultural learning, will tend to become more prevalent in a society over time (Kelly 1995: 52). The important point here is that behavior can be inherited through both genetic and cultural (learned) mechanisms, akin to the distinctions between Darwinian and Lamarckian evolution (genetic inheritance and the inheritance of learned behavior). Therefore, behaviors that confer some sort of adaptive advantage on an individual, and are heritable (via either genetics or cultural learning), should increase in frequency within a population until they are replaced, or conditions change and favor an alternative adaptation. From the perspective of the archaeological record,

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specific conditions that increases the organism's ability to outcompete and ultimately out reproduce other organisms, thus passing the trait on.

[3] It is important to realize, however, that the expectation of optimal foraging is very closely tied to the risk, or perceived risk, associated with sub-optimal strategies. In other words, in the absence of some negative consequence associated with a given activity, there is no contextual push to favor one trait or one strategy over another. Therefore, outside the context of clearly identified risk, there are not the necessary requirements for traditional selectionist evolution (phenotypes linked to increased fitness), and the implications of those evolutionary based theories are not justified.

the material correlates of those specific behaviors can be monitored through time as a proxy of the evolution of those behaviors. As O'Brien et al. state (1994: 261): "materials contained in the archaeological record were parts of human phenotypes, as were behaviors behind the manufacture, use, exchange, and eventual discard of the materials. Viewed as such, those materials and behaviors can contribute as much information regarding human adaptedness and adaptation as can analysis of purely biological features" (1994: 261).

Therefore, Optimal Foraging theory, in its most basic form, and applied to hunter-gatherer subsistence technology, argues that foragers will adopt strategies to maximize the *net rate of return* (in terms of caloric energy, nutrients or some other currency) while minimizing the *costs*, the time and energy expended procuring food resources. Additionally, in the context of prolonged adaptation to a specific ecological context, groups that adopt 'optimal' strategies should have an advantage over groups that do not. Groups that do pursue 'optimal' (or more 'optimal') subsistence strategies acquire their basic necessities in a more timely, efficient manner, and are able to allocate more time and energy to other productive tasks, and therefore reify the advantage of optimizing subsistence strategies[4] (Bettinger 1987; Bettinger 2009; Smith 1983; Smith and Winterhalder 1985; Winterhalder 1980; Winterhalder 1983; Winterhalder 1986; Winterhalder 2001; Winterhalder and Kennett 2009; Winterhalder and Smith 2000). Accordingly, in the context of expending the least energy and acquiring the greatest reward, optimal foraging hypothesizes foragers will systematically target the highest ranked resources available to them, and with intensity, that mirrors that resources availability on the landscape.

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[4] Traditional Darwinian evolutionary theory dictates that the advantage of a given trait must have a direct implication of reproductive success, or *reproductive fitness*, since the trait must be heritable and passed on for some time before it can be seen within a lineage, or within the archaeological record. Traditional Optimal Foraging theory argues that the increases in time available for non-subsistence related tasks can, and is, often directed towards creating, and nurturing young.

Given the high processing requirements of plant food resources, relative to meat resources, aboriginal foragers should prefer to take game, particularly large game, when available, and focus on large animal resources almost exclusively when they are in abundance. Additionally, as large game resources are depleted, or otherwise unavailable, human foragers should progressively broaden their diets to include progressively lower-ranked resources, and in comparatively higher numbers, in an effort to offset the decreasing returns associated with the decreasing availability of high-ranked resources (Figure 8-3).

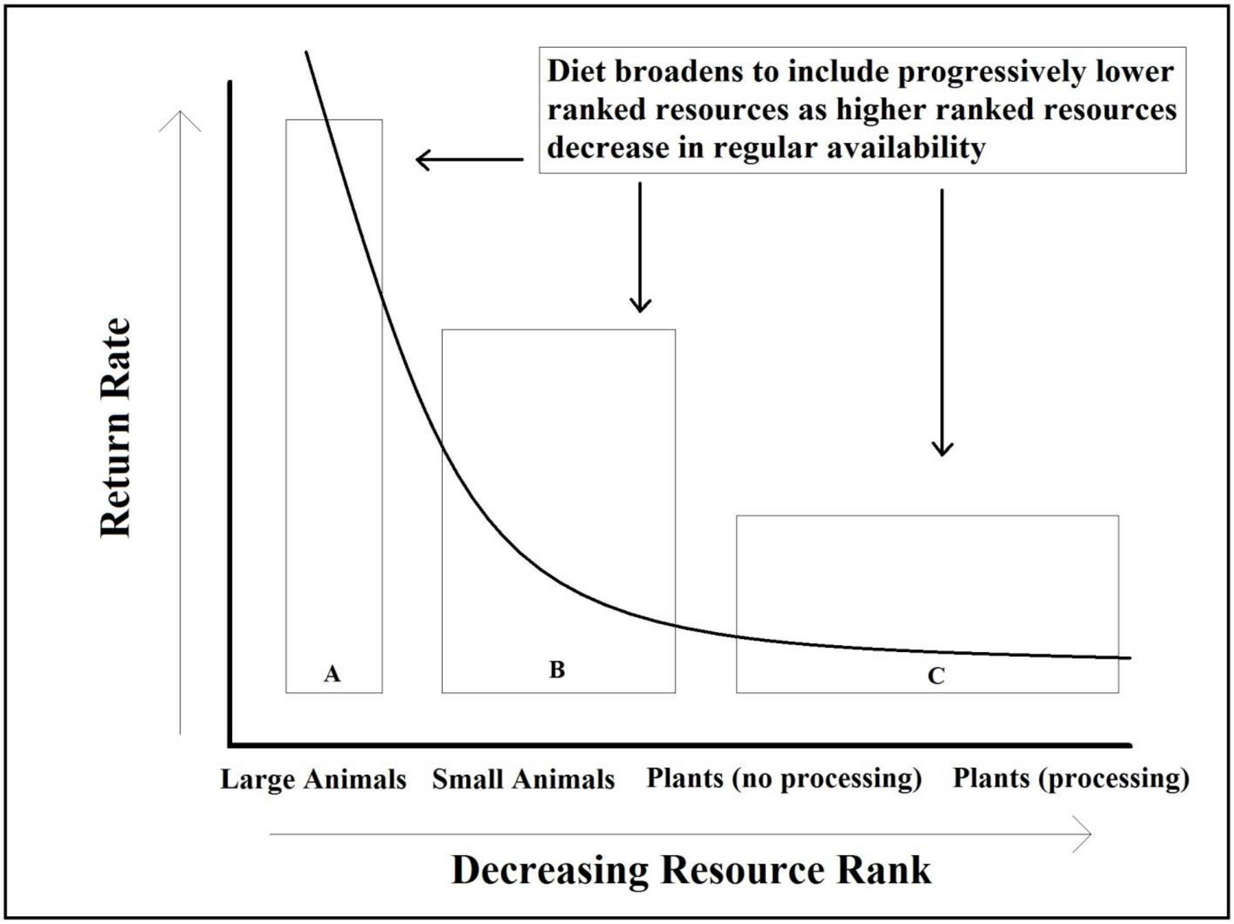


Figure 8-3: Generalized diet-breadth model of foraging behavior

Taken together, these ideas provide a working model of feature use and change that I use to interpret the archaeological record. Specifically, the inclusion of stone as a heating element in feature design signals adaptive changes in subsistence strategies towards a greater reliance on low-ranked, high-cost plant foods. During periods of resource stress, defined as the progressive decreasing availability of high-ranked resources, the archaeological record should testify to increases in dietary breadth in the form of rock-filled hearths. Alternatively, during periods of resource abundance, defined as the progressive increasing availability of high-ranked resources, we would expect to see rock-less hearths reflecting relatively narrow diets that emphasize high-ranked, low-cost resources that require very little processing and therefore, provide little impetus for feature elaboration. Following the working model for the evolution of thermal feature morphology proposed by Thoms (2009), we expect populations to generally increase through time, and the frequency of rock-inclusive feature designs to increase in concert.

Stiger (2001) has found thermal features in the Gunnison Basin of west-central Colorado to follow an evolutionary trend not unlike that predicted by Thoms. Specifically, Stiger analyzed 160 radiocarbon dated hearth features and noted a time-progressive evolution to feature design that begins with unlined features, and progressively includes boiling pits, rock-lined hearths, and fire-cracked rock hearths (with a decrease in size of these features through time). Within the Gunnison Basin, rock-lined features are far more frequent than in northern Colorado and are heavily used in the period dating between 5000 and 7000 cal BP. Fire-cracked rock features are the most frequent feature type after 3000 cal BP, when rock-lined features disappear entirely. Broadly, the data presented by Stiger suggest periods of intensive plant use centered on the Early Archaic (5-8k cal BP) and the Late Archaic/Late Prehistoric periods (1-3k cal BP; 2001:108).

Cook stones are not a regular part of the technological system of northern Colorado peoples until around 8000 cal BP, post-dating the first appearance of humans by at least 4000 years. Within the context of Optimal Foraging theory, the combination of high faunal diversity, availability, and low overall human population density that characterizes the earliest periods of

North American prehistory would have favored large game hunting strategies. In the context of the dietary breadth model, we would expect to see strategies that emphasize large animal procurement preempt those that include lower-ranked animal and plant resources. The available evidence regarding Paleoindian subsistence indicates that intensive plant processing was not a routine part of the diet. Moreover, the Paleoindian record is dominated by unambiguous, pervasive, widespread evidence of large animal resource extraction and a dearth of formal variation in thermal feature design. With regard to one of the few Paleoindian sites with extensive evidence of thermal feature use, the Barton Gulch site, yielded 75 individual features, and grouped into 37 distinct clusters representing 4 separate loci of activity (Armstrong 1993). The features were all unlined and nearly identical is shape and size. Hearths could still provide heat and light, and cook meat, but these basic functions did not require elaborations in feature design; the limited number of functional roles of these features did not necessitate the addition of rock. Looking at the temporal distribution of the various feature types in northern Colorado (including two forms that include rock – FCR in the fill and slabs lining the sides and bottom), it is clear that the single unlined feature form characterizes the early period.

Given the processing requirements associated with intensive geophytic plant use discussed above, these unlined features represent the backdrop against which we may understand the timing of incorporation of rock-filled features and intensive plant use into prehistoric subsistence practices. These features themselves do not represent geophytic plant processing locales, rather general-purpose fires that were at least partially used for meat and other low-cost food processing. They appear early in the Paleoindian period and persist well into the Protohistoric. They consistently appear at high elevations throughout the periods discussed here, and are sporadically represented at lower elevations, particularly on the Plains in the eastern part of the study area.

Alternatively, beginning in the early Archaic, more elaborate, rock-inclusive forms are included in the technological system. The appearance of these new forms is consistent with increases in groundstone in archaeological assemblages, a pattern that began in the late Paleoindian period, but expands and reaches diagnostic distinction in the early Archaic (Frison 1998). There is also a concomitant increase in the representation of small animals and a dramatic decrease in the number and size of bison kills dating to this period. Archaic Period subsistence evidence is plentiful, and in general, suggests a rapid expansion of diet (in terms of the diversity of food sources), and an increase in the use of small animals, and low-yield plant foods. Broadly, the occurrence of rock-inclusive features correlates strongly with other evidence of dietary expansion beginning around 8,000 cal BP. Of particular importance, Early Archaic peoples intensified plant resources through the use of rock-inclusive hearth features on the plains and within the foothills, but in this early period of rock-filled hearth use, people did not utilize these features and the resources made available through their use in the higher elevations; that would not begin for another 2000 years.

Following initial appearance, the absolute frequency of FCR hearths increases steadily, through time (Figure 8-4), and Thoms' (2009) FCR feature density model accurately describes the evolution of thermal feature morphology in northern Colorado. The frequency of FCR hearths increases predictably through time, with variations on the scale of decades and centuries. The frequency and distribution of unlined hearths tells a subtly different story, however, and a comprehensive understanding of FCR hearth morphology and use must take into account temporal patterns within alternative feature type distributions. More to the point, unlined feature counts on the landscape increase sharply around 7000 cal BP and then decrease sharply shortly thereafter, reaching near zero representation around 5000 cal BP (Figure 8-4). In terms of the percent representation, the archaeological record is dominated entirely by FCR features during at least two points in the past, and FCR hearths represent over 75 percent of all features dating between 4000 and 5000 cal BP. While the working model of feature evolution presented above accurately predicts overall trends in rock-inclusive hearth feature frequency, and fits the expectation of a progressive increase in FCR features through time, there are periods where FCR features make up a much larger part of the entire hearth system. At specific points in the past, and in coordination with other evidence of climatic stress and increases in dietary breadth, humans clearly relied on FCR hearths, and the apparent plant resources made available through their use, to a much greater degree (Figure 8-4 and 8-5). In northern Colorado, the initial intensification of low ranked plant foods does not take place in response to a significant increase in population, rather a decrease in available land suitable for various resource extraction strategies, thus forcing past peoples to do more with less, and extract more food and resources from a less productive landscape.

Table 8-1: Percent and frequency representation of rock in hearth feature design

Thermal Feature Design	Frequency		Percent	
	No Rock	Rock	No Rock	Rock
Paleoindian	10	0	100	0
Archaic	44	31	59	41
Late Prehistoric	45	50	47	53

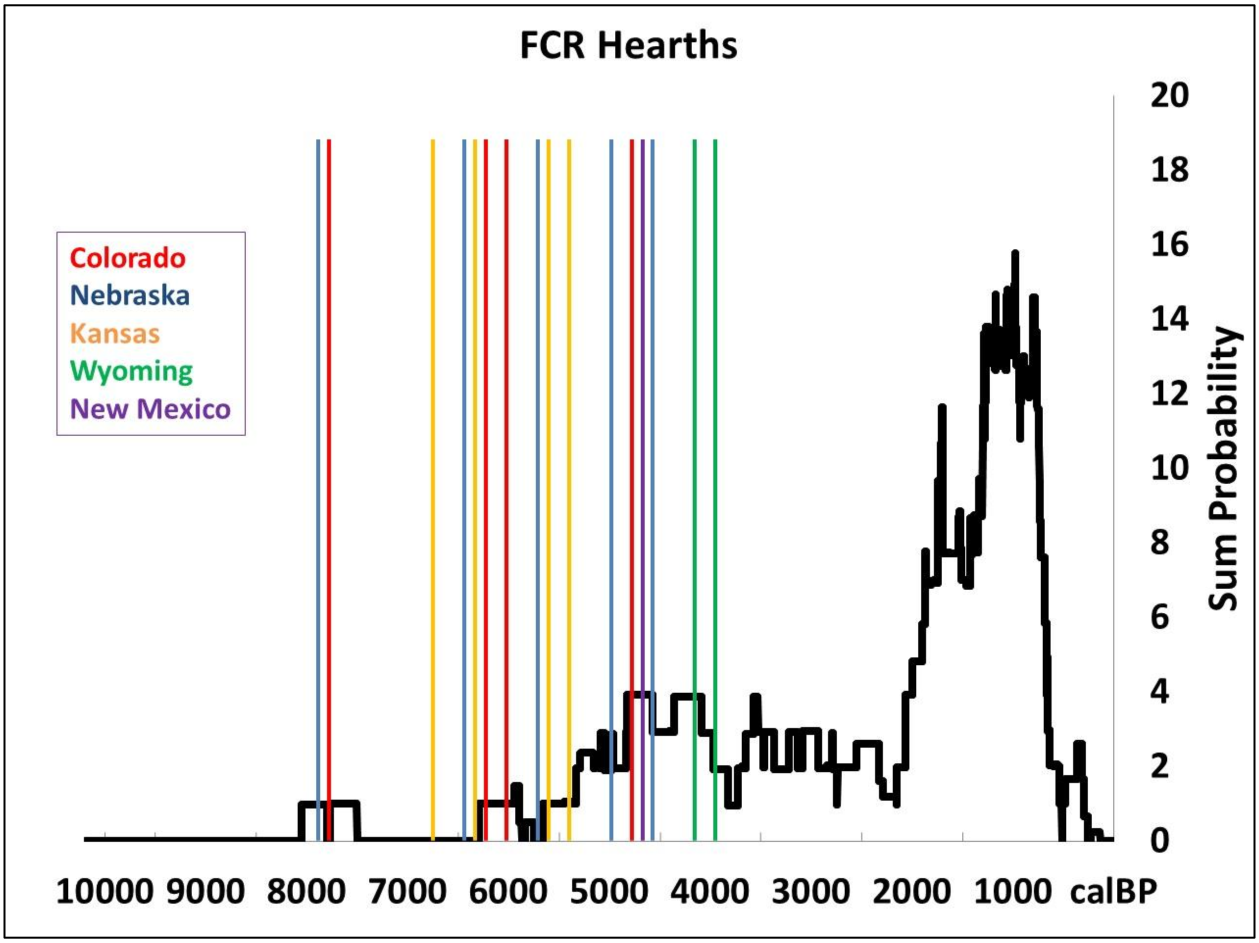


Figure 8-4: Frequency representation of FCR hearths and select dune mobilization events from Colorado and adjacent states

The difference between rock-inclusive features and unlined features is less distinct in the periods following 4000 cal BP, or in terms of cultural periods, following the transition from the Middle to Late Archaic period, there is continuity between Middle Archaic and Late Archaic strategies. Once Middle Holocene conditions ameliorated, sometime around 4000 radiocarbon years before present, large animal populations and subsequent usage by humans apparently increased in the Wyoming Basin (Byers et al. 2005), and large animal meat became a large part of hunter-gatherer diet once again. However, FCR features do not disappear with the return of more intensive large animal procurement strategies, and in fact increase to within the last 1000 years.

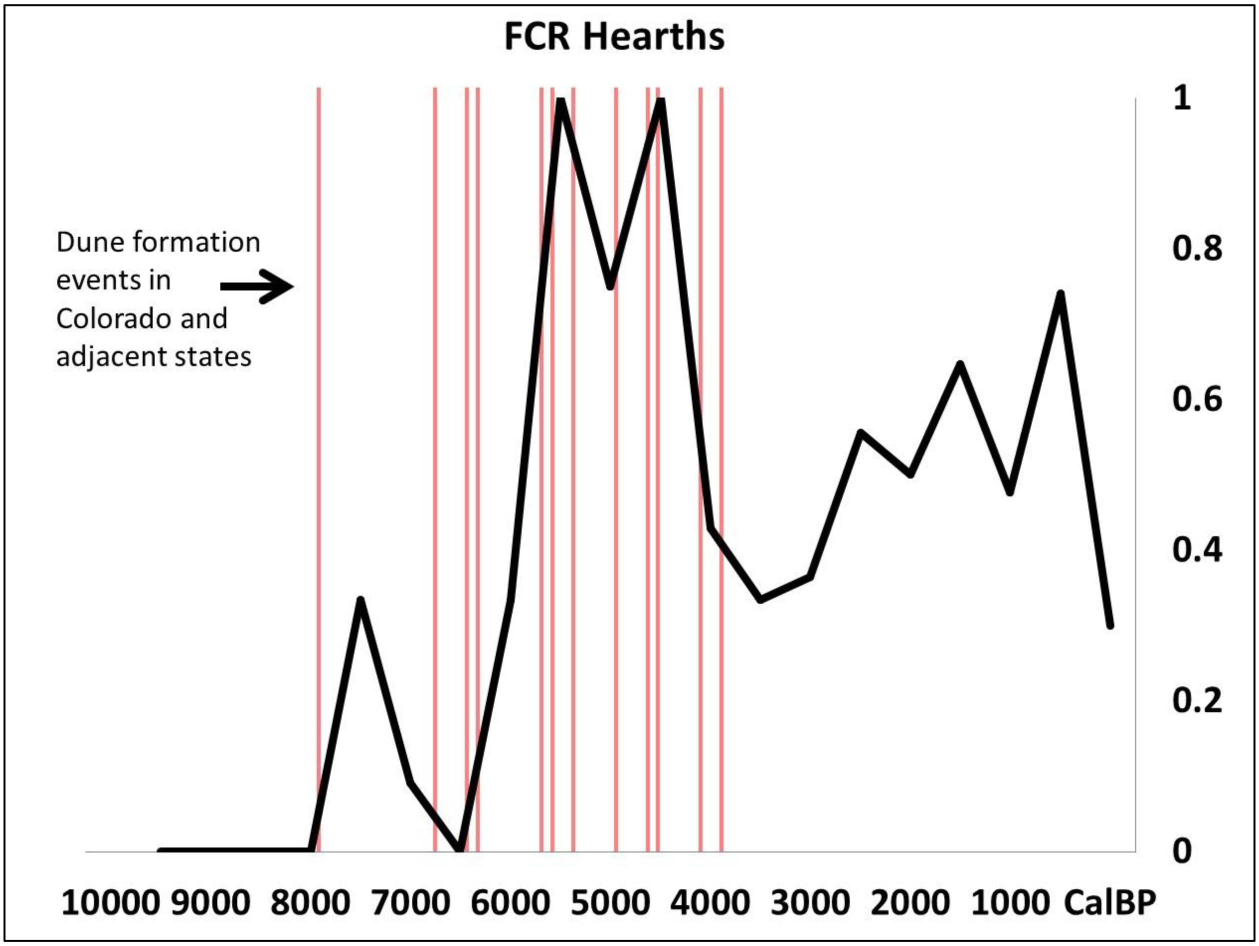


Figure 8-5: Percent representation of FCR hearths and select dune mobilization events from Colorado and adjacent states

Indeed, once incorporated into the technological system, rock-inclusive features continue to be used. More to the point, they appear at progressively higher elevations, through time. During the period following 6000 cal BP, rock-inclusive features move from the plains to the mountain zone. The first FCR feature within the study area comes from the Willow Bunker site (5WL1656; Feature 20), and appears sometime between 8052 and 7794 cal BP on the lower elevation plains. The next FCR hearth within the study area also comes from the site 5WL1656 (Feature 1) and dates to sometime between 7762 and 7500 cal BP. Fire-cracked rock features are absent thereafter until 6293 cal BP, at which time middle and lower elevation FCR hearth representation increases steadily until around 2000 years ago. Alternatively, the first fire-cracked rock feature above 3000 m dates between 2064 and 1696 cal BP, almost 6000 years after the first appearance of FCR features on the plains. Fire-cracked feature representation in the alpine/subalpine increases to rival the lower mountain zone by around 1200 cal BP. Shortly thereafter (just before 1000 calibrated years ago), fire-cracked rock feature representation at the lowest elevations reaches the zenith of FCR representation of any period and any elevation.

Following the hypothesis discussed herein, the appearance of FCR, or rock-filled hearths in the archaeological record attests to periods of relative increases in dietary breadth. Table 8-2 illustrates the inferred dietary breadth of the major cultural periods and elevations under study, as interpreted by the distribution and abundance of rock-filled hearth features. The earliest periods, at all elevations are characterized by low overall dietary breadth; this interpretation is supported by the broad patterns suggested with regard to the available Paleoindian subsistence evidence. During the Early Archaic, the first FCR features appear within the lowest elevations, and suggest subtle increases in dietary breadth. Importantly, these rock-inclusive features do not appear at other elevations at this time, and the middle and higher ranges continue to be characterized by low overall dietary breadth. This would seem to suggest that the climatic impetus for increasing dietary breath was not present in the higher elevations at this time. Though we tend to think of past inhabitants of the Southern Rocky Mountains as seasonally mobile, and utilizing the higher elevation areas and resources on a seasonal basis, as they become available (Benedict 1992), there is growing evidence of an increasingly localized and more sedentary mountain culture centered on the high country during the Early Archaic Period (the Yarmony Pithouse Site, Metcalf and Black 1999; the Tenderfoot Site, Stiger 2001). Whatever the case may be, whether

Early Archaic peoples within the study area used the high country in a transitory or more sedentary fashion, they did not intensify low-ranked plants, and did not build rock-filled hearths.

Table 8-2: Percentage of all features containing and inferred patterns in dietary breadth arrayed by cultural stage and elevation – red cells indicate high inferred dietary breadth, orange cells indicate medium inferred dietary breadth

Percent Rock and Inferred Dietary Breadth				
Cultural Period	**Approximate Date Range cal BP**	**Elevation**		
		<2k m	**2-3k m**	**>3k m**
Late Prehistoric	1850-400	53	64	48
Late Archaic	3000-1850	56	100	50
Middle Archaic	5000-3000	45	56	0
Early Archaic	8000-5000	33	36	0
Paleoindian	Pre 8000	0	0	0

During the Middle Archaic, people expanded on the patterns begun in the Early Archaic: the use of groundstone and other complex tool types aimed at diverse processing strategies increases, and there appears to be increasing use of plants. To the list of evidence in support of Middle Archaic plant use, we may add trends in hearth morphology; rock-filled hearths persist on the plains during this period, are well-represented with regard to unlined hearths, and make the first appearance above 2000 meters. Middle Archaic FCR features above 2000 meters are broadly comparable in frequency to unlined features, suggesting a broad diet.

The Late Archaic period, broadly, is characterized by a subtle amelioration of Middle-Holocene conditions and a return of large animal procurement strategies (Kornfeld et al. 2010: 255-268), and certain Late Archaic cultures return to a highly mobile, bison-oriented subsistence economy (e.g. Yonkee, Besant). The Late Archaic hearth record broadly follows the patterns established in the preceding period, albeit with an across-the-board decrease in intensity; unlined features increase in frequency at this time and the percent representation of rock-filled features decreases.

Lastly, during the Late Prehistoric Period (1850-400 cal BP) initial trends in subsistence are similar to the preceding Late Archaic, but the eventual introduction of the bow-and-arrow and ceramic technology, and apparent increases in population density create systemic changes in mobility and settlement strategies, and suggest increasing relative permanence of place and increasing reliance on plant resources (Gilmore 1999: 236-240). Indeed, horticulture is well underway in other parts of North America at this time. FCR hearth frequency and distribution largely mirrors that of other feature types at this time and suggests increases in dietary breadth at all elevation ranges.

The initial appearance of FCR features and subsequent progression through time does not appear to be a coincidence. In fact, in contrast to unlined features, the first FCR hearths date very near the beginning of the Altithermal drought that affected much of the North American Great Plains during the Early/Middle Holocene (Antevs 1955; Benedict 1978; Meltzer 1991; Meltzer and Collins 1987) and progress uphill on the order of around 1000 meters higher every 2000 years. The later appearance of FCR features in the Rocky Mountains seems consistent with the progression of the mid-Holocene drought event as it slowly and progressively affected the better-watered higher elevation regions. Specific climatic data are needed to support the assertion that the effect of the Altithermal drought is differentially experienced based on elevation. The logic however, is simple: as drought reduced precipitation on the plains, both warm-season rainfall as well as winter snowfall, the higher elevations, due to the effect of altitude, retained seasonal moisture and winter snowfall for longer, there by buffering the effect of the drought as a function of altitude. Benedict has argued that the highest elevations are effectively “drought-proof”, given the abundance of glacial runoff, rainfall, and late-lying snow banks (1979, 1991).

The necessary question then arises as to why these features were employed at high elevations, albeit very late in time (post-1860 cal BP), why intensify the use of plant resources if higher-ranked resource abundance at the regional level is high relative to preceding periods? Though I cannot provide a conclusive answer at this point, I believe there are a few points worth exploring with future research that largely focus on the possibility of potential local, short-term shortfalls in high ranked resources. First, the timing of the presence of rock-filled hearths at elevation coincides with population growth across northern Colorado (Gilmore 1999, 2008). Evidence of increasing utilization of the high country is principally manifested in high frequencies of small, Early Ceramic-era corner-notched projectile points as well as the expansion of associated game drive systems (Benedict 1975, 1996, 2000, 2002, 2005; LaBelle and Pelton 2013). Given the apparent connection between hearth feature elaboration and possible population expansion, one hypothesis may point towards increasing competition for critical resources and the concomitant increasing importance of seasonally- available foods. That is, prior to the Late Prehistoric period, if animals were not forthcoming at the game drive sites in a given year, those earlier peoples could simply move on. After populations increased, however, those seasonally available resources became more important and flexibility in the annual schedule decreased due to increasing competition. Thus, people may have turned to intensive plant exploitation as a means to deal with local shortfalls as part of a larger effort to extract animal resources from the high country. Similarly, we cannot discount the possibility that intensification of plant resources helped fund the costly process of game drive expansion; a tighter chronology on the specific expansion events and correlations with both rock-filled hearths as well as other evidence of plant use (groundstone) would help elucidate this issue (Pelton 2013).

CHAPTER 9 CONCLUSIONS

In conclusion, the thermal feature record of northern Colorado suggests there are meaningful differences in the distribution of feature types and sizes through both time and space. Returning to the questions that have guided this research, I will now specifically address these questions with the data at hand. While not all questions were answered to the same extent, and in the same detail, there are noteworthy points regarding each of the questions, as explicitly asked, and with regard to issues not fully appreciated or predicted at the beginning of this work.

1.) <u>Are there temporal and spatial patterns to hearth morphology</u>?

There are both spatial and temporal patterns in the distribution of particular feature types throughout the study area. There are at least three clearly identifiable feature types: unlined; rock-filled or FCR hearths; and rock-lined (elsewhere referred to as slab-lined – see Chapter 4). Rock-lined features are rare within the study area and require more investigation, and at a larger scale; there are only nine such features within the counties identified by this study, but adjacent areas contain more of these features (particularly southern Wyoming, and the Gunnison Basin), and at times when these features are not represented in the study area. Furthermore, within the study area, the latest of these features occur in sheltered campsite contexts (rock-shelters), and may reflect a desire to manipulate heat dispersion within those contexts as much as control heating and cooking properties and conditions.

More to the point, the prehistoric record of feature use in northern Colorado is characterized by a dichotomy between unlined hearths and rock-filled hearths. Unlined features appear first and are represented throughout the prehistoric past. Specifically, the Paleoindian Period is characterized by unlined features above 2000 meters, with very few features below 2000 m at this time. The Early Archaic Period is initially characterized by a mixed representation of lower and middle elevations, with increasing number of hearths in higher elevations as time progresses. All feature types disappear just after 6000 cal BP, and the Early Archaic Period concludes with nearly no unlined hearth signal. Unlined features gradually recover across all elevations throughout the first half of the Middle Archaic Period, after which the middle and upper elevations level off, and the lowest elevations increase to an unprecedented high. Following a brief downturn around 3000 cal BP, unlined features increase once again across all elevations to the peak around 1000 cal BP and rapidly decrease thereafter.

Alternatively, rock-filled hearths are entirely absent from the Paleoindian record, and appear around 8000 cal BP, in association with other sweeping, systemic changes in subsistence, technology, and landscape use. The utilization of rock-filled features corresponds with other evidence of increasing dietary breadth, and decreasing use of large animal resources. Progressively, these features appear at higher and higher elevations, reaching areas between 2 and 3 thousand meters around 6000 cal BP, doubling in frequency at this elevation around 4000 cal BP, and reaching areas above 3000 meters (which have been used by humans, since very near their first appearance in North America) only within the last 2000 years. The uphill progression of these features suggests that the impetus for feature elaboration was differentially experienced based on elevation. More specifically, given the hypothesis outlined earlier, the inclusion of low-ranked food resources is tempered by elevation, with people including geophytic plant foods at high elevations only very recently. Given that we are likely not dealing with discrete groups using each of these elevations ranges exclusively, but rather groups using more or less all elevation ranges in the course of a given year, based upon seasonal scheduling, the inclusion of these low-ranked foods above 3000 meters indicates that there are significant changes within the last 2000 years in the way in which the high country is incorporated into seasonal mobility strategies; the use of rock-filled hearths at this elevation may be a result of an attempt to meet a local need, or perhaps an effort to address shortfalls elsewhere in the seasonal system.

In terms of size and shape, the data suggest that prehistoric Northern Colorado residents constructed hearths of various sizes independent of feature type, and independent of time. Specifically, patterns in unlined feature diameter through space and time do not demonstrate significant differences. The diameter and variance of unlined features across cultural periods and elevations is effectively equal. On the other hand, depth comparisons between unlined features from different elevations do, in some cases, demonstrate significant differences in depth. Understandably, however, there are geologic depositional considerations that must be more fully addressed (particularly the difference in soil depth across sites from these elevation ranges, and the variable effect of erosion and other taphonomic forces) before these differences in feature depth may be queried in the context of human behavior.

Fire-cracked rock hearths on the other hand, illustrate more spatial diversity and distinction. Specifically, features above 3 thousand meters differ statistically (in terms of depth and diameter) from features located in the 2-3 thousand meter range, as well as below 2 thousand meters. On the other hand, the lowest and middle elevations do not differ statistically in terms of either depth or diameter from one another. Thus, it appears that while unlined feature depth differs, variably, between various elevation ranges, there is a clear pattern towards wider and deeper fire-cracked rock features at lower elevations, and smaller and shallower features above 3 thousand meters. Given the inherent permanence of rock-filled features relative to unlined features, depth and diameter measurements may be more reliable, assuming that care is taken to identify intact features, and not secondarily deposited fire-altered rock.

2.) <u>Are there spatial and temporal patterns in the material recovered from hearth features</u>?

Unfortunately, one unforeseen result of this research is recognition of the fact that few of the dated hearth features in northern Colorado have been analyzed for macrobotanical or macrofloral remains, and few of those have produced conclusive results. Specifically, when considering all feature types collectively, fewer than 10 percent have an associated macrobotanical ID, and fewer than 25 percent produced identifiable fuel wood. In accord with what one would expect given a strictly taphonomic interpretation of plant feature preservation, there is a general trend towards the greatest representation of plant material at the lowest elevations, and in the most recent past. However, taphonomic effects aside, features from the highest elevation are generally more thoroughly analyzed, and likely reflect the excellent work of the late James Benedict (1973, 1979, 1981, 1985, 1991, 1993, 1996, 1998, 2000, 2005; Benedict and Olson 1978), who spent his professional career contributing to a high elevation archaeological record that would have otherwise gone largely unnoticed and unstudied.

While there may be a number of unknown factors resulting in the underrepresentation or lack of representation of plant materials in hearth features, amongst the known factors, the detailed analysis of macrobotanical materials is not as widely practiced as one might hope. Despite the ease and low-cost of macrobotanical flotation, many features are excavated, dated, and described without an associated analysis of feature plant content. More often, archaeologists screen, identify, and record lithic and bone, and disregard or overlook the potential for plant material. Macrofloral analysis must become a more routine part of hearth feature analysis before the question of temporal and spatial patterning in feature contents can be fully and adequately addressed.

That being said however, and with the notable exception of the Harvester Site hearth (see Chapter 5), eight various features excavated by the Colorado State University Archeological

Field School between the years 2009 and 2011 were analyzed for macrobotanical remains, and all failed to produce any identifiable plant materials other than fuel wood (see Appendix C). Given the rock-inclusive feature designs and intensive plant use interpretations presented above, the question naturally arises as to why northern Colorado rock-filled features intensively recorded, sampled, and analyzed still show no plant signature. Turning to the hypothesis outlined in this work (the connection between rock use in feature design and geophytic plant use), we must naturally ask what the material signature of root processing would look like. Ethnographic examples of such processing (Wandsnider 1997: 10-18) suggest that once the cook stones were heated, root foods were gathered in a large quantity and layered with other plant material (leaves, cacti pads) and placed directly on the hot stones and subsequently buried. Once the material had cooked the requisite amount of time, the earthen cap was removed and the plant material, food or otherwise, was removed. In this example, the target food material was deliberately removed in its entirety. It is possible, particularly given the size of typical root foods, as compared to seeds and other ethnographically utilized plant parts, that past peoples effectively and completely recovered the processed plant materials. Alternatively, the specific biochemical characteristics of root foods may also contribute to poor preservation, and leftover foods (particularly following complex carbohydrate hydrolysis) may be a prime target for consumption by other animals. Whatever the case may be, we do not find remains of root foods in hearths in northern Colorado at all, so whatever the material signature of such processing is, it does not last; future inquiries will do well to pursue alternative methods at identifying the remains of root foods.

3.) <u>Do changes in hearth morphology through time coincide with documented changes in paleoclimate and other systemic changes in prehistoric culture</u>?

Broadly, there are three significant events in the history of hearth use in Northern Colorado: the first appearance and proliferation of rock-inclusive features during the Early and Middle Archaic periods; the uphill progression of rock-inclusive features through time, culminating with the incorporation of these features above 3000 meters in the last 2000 years; and the significant increase in the representation of all features, and the near equal proportion of rock-less and rock-inclusive features at all elevations within the last 2000 years.

The initial appearance of rock-inclusive feature designs takes place at, or very near the beginning of the well-documented Middle Holocene drought, or Altithermal (Antevs 1955; Benedict 1978; Meltzer 1991; Meltzer and Collins 1987). Unlined features predate the appearance of rock-inclusive ones by over 2000 years, and rock-inclusive feature designs follow the initial appearance of humans by at least 4000 years. During this earliest period, there are at least 10 examples of unlined features within the study area. Furthermore, despite the greater potential for destruction of rock-less features, compared to rock-inclusive ones, unlined hearth features routinely occur on Paleoindian sites across the plains, and there are examples of Paleoindian-aged sites with evidence of burning, but without identifiable hearth features (The Claypool Site 5WN18, Stewart's Cattle Guard Site 5AL101, and Barger Gulch Locality B 5GA3827; LaBelle 2005).

Though they persist into later periods, the origin and initial development of FCR hearth features technology rests squarely within the Archaic Period of regional prehistory. The Archaic lifeway represents a broad suite of systemic changes in landscape use and prehistoric subsistence and material culture. The available evidence suggests that Archaic diets broadened around 8000 BP to include a variety of plant and small animal resources. Concomitant changes in the size and composition of Archaic toolkits, and the frequency and intensity of groundstone use parallel the appearance of rock-inclusive feature designs and collectively indicate a systemic change in food procurement and processing strategies.

The uphill progression of these features through the Middle and Late Archaic Periods is not as definitively associated with sweeping changes in other material culture, and is not tied to any well-known climatic event. Indeed, the transition between the Early and Middle Archaic periods, and the Middle and Late Archaic Periods are much less distinctive than changes between the Paleoindian and Archaic Periods, and later, the Archaic and Late Prehistoric. However, given the hypothesis outlined herein, the appearance of these features at higher elevations suggests that people progressively intensified plant resources in the middle elevations of the Southern Rocky Mountains, beginning in earnest around 4000 cal BP, and reaching areas above 3000 meters within the last 2000 years. It is not entirely clear how these features were incorporated into seasonal rounds of the mountain country, and the use of these features in association with high altitude game drive sites is a promising avenue for future research.

Lastly, all features increase significantly within the last 2000 radiocarbon years, including the high county, but particularly the lowest elevations. The last 2000 years correlate with the transition from the Late Archaic Period to the Late Prehistoric. Though there is initial continuity in subsistence strategies between the two periods, technological developments (or adoptions) within the Late Prehistoric Period are significant and enduring and have a considerable impact on past human organization. Notably, the bow-and-arrow and ceramic technology appear around this time, and signal the beginning of a suite of human adaptations including an increased reliance of domesticated (or semi-domesticated) plants, and decreased seasonal mobility (Gilmore 1999). This period in many parts of the west culminates with near-sedentary village life and all the associated lifestyle changes associated with that sort of permanence of place (though not in the study area specifically). Additionally, and not unrelated, population density at this times appears to increase sharply. Indeed, the Late Prehistoric period is the best represented period of regional prehistory. Small, side and corner-notched projectile points are often used to distinguish this period from preceding periods, and suggest that and animal meat was still a large part of the diet. Proliferation of rock-inclusive features at this time suggests that once catalyzed within the system, FCR features were still useful (and perhaps necessary) to meet the increasing need associated with more people on the landscape.

Returning to the research gaps this work seeks to address and the specific aims of this research outlined in Chapter 1, this work contributes four things. First, I have proposed a system of hearth identification and classification applicable to large, landscape level studies of hearth distribution. Secondly, this research has resulted in the development of a database of nearly 200 radiocarbon dated features from northern Colorado with associated ^{14}C and macrobotanical data, and, third, an evolutionary model for understanding changes in feature morphology and use that incorporates a functional interpretation of feature design, specifics of food biochemistry, and a selectionist evolutionary theoretical basis that structures hearth use within a least-cost behavioral framework. Lastly, the present work has provided an assessment of changes in feature morphology through time and possible impetuses. Collectively these contributions provide a spring board for future inquires aimed at understanding specific questions regarding spatial and temporal variation in hearth size and design (see Future Research heading below).

However, there are clear limitations to this sort of approach, and limitations to the datasets at hand. First of all, a landscape level interpretation presupposes that the variable role and idiosyncratic decision-making of individuals is invisible, or at least negligible in influencing the landscape-level archaeological signature. Understandably, there will be examples (as with the ethnographic examples hearth use outlined by Wandsnider 1997) of feature use not altogether in accord with the hypothesis outlined above. At any given moment throughout the past an individual may have chosen to pursue a resource based on their own individual tastes or any other unknown sociocultural reasons, such as a particular spiritual or ceremonial function or role of a specific resource. Additionally, a strictly subsistence interpretation of feature design ignores the role of plant resources in other parts of utilitarian culture, such as fiber and other tool functions, and non-utilitarian culture such as medicine, art, and ceremony. However, the question is really a matter of frequency and proportion, that is how often is a specific feature used for an explicitly non-subsistence related function, and how often is it used to cook food. And, applied to a larger scale, how many features on the landscape were used for ceremonial functions, and how many were used for subsistence-related tasks. This work presupposes that while non-subsistence activities were a significant part of past culture, non-subsistence uses of hearth features in contrast to the subsistence-based hypothesis outlined herein, are small and effectively invisible at this scale. More to the point, construction of an elaborate rock-filled hearth represents a very real labor and material investment, and the costs associated with construction and use is generally prohibitive except where absolutely necessary. In the context of Optimal Foraging Theory, such behavior represents sub-optimal strategies that should not persist through time and ultimately will not result in a distinctive archaeological signature. This selectionist-based argument is more compelling given a clearly defined risk context; the greater the risk associated with sub-optimal strategies, the greater the selective force against that phenotype or behavior. In the context of environmental stress, the distribution and abundance of ‘critical’ resources, that is those necessary for hunter-gatherer survival, necessarily change and the composition of the ‘critical’ resource base may also change. Binford (1980) postulates that as environmental stress increases there is concomitant increasing incongruity in the distribution of resources, an increase in the number of critical resources included in the diet, and changes in human landscape-use patterns aimed at meeting subsistence needs under these changing conditions. In other words, as climatic stress increases, individual resources become more important (there are fewer of them), and generally tend to become more unevenly distributed across the landscape (incongruent). Under these conditions, following Binford, we expect changes in human land use patterns that allow access to the widest variety of critical resources, while minimizing the risks and costs associated with procuring them. Accordingly, the appearance of FCR hearths near the beginning of a regional, two-thousand-year-drought represents an adaptation in the face of extensive and pervasive risk, and a strong selective force against sub-optimal strategies.

Another shortcoming of this approach is the inability to understand how individual features are structured within individual site contexts. Specifically, the present approach treats all features of the same kind as representatives of the same behavior. There are clear reasons to assume that this is not always accurate. First, fine-grained investigations of site structure routinely indicate that past peoples, at times, differentiated tasks spatially within a site. In that context, it is possible that two features of the same type, on the same site may fill functionally unrelated roles. Additionally, there are compounding differences associated with a productive task that requires more than one feature, or more than one feature type. An example of such behavior would be the bone grease boiling process seen elsewhere on the Great Plains (Kornfeld et al. 2010: 255, 271, 276, 297). Bone boiling features have been recorded and appear to require both an unlined feature for heating stones, and a paired feature for heating water with the hot stones (within which the bone fragments are boiled, and the marrow rendered; Thoms 2008: 446). While it does not appear that bone boiling was routinely practiced in northern Colorado, the present study only considers a subset of all hearths recorded within the study area; specifically, the present study only considers radiocarbon dated features and does not include other temporally indistinct features (often from the same sites). Thus, both with regard to the scale of inquiry, as well as the nature of the selected data set, there are potential issues of feature interrelatedness that cannot be fully appreciated within the present research design, and site level dynamics that ultimately must be addressed. It is within the context of these finer-grained, site-level inquiries that the merits of the hypothesis outlined herein ultimately will be tested.

Lastly, perhaps the greatest weakness regarding the applicability of the present research centers on the coordination between environment and human behavioral data. Correlation is not causation, but there are hints of patterned relationships between environmental conditions and human decision-making in the archaeological record. However, the issue is one of scale. Specifically, are the respective scales of data appropriate for comparison? The archaeological record represents the small accumulation of individual decisions made at specific points in time, and in very specific contexts, both real and perceived (as interpreted by the decision-making individual). The present research includes 191 radiocarbon dated hearth features, but does not include 191 individual, site-specific paleoenvironmental records. The scale of paleoenvironmental data is very coarse in comparison to the individual and aggregate, instantaneous human decisions that we seek to understand. Naturally, more refined paleoenvironmental data is necessary to fully address the hypothesis outlined herein, and carry on the effort in more detail.

Future Research

The aforementioned shortcomings aside, this work has provided a preliminary attempt at understanding thermal feature variation in northern Colorado. Due to the scope of the present project, there are many questions about thermal feature morphology and spatial and temporal distribution that were regrettably left unaddressed. Moreover, the results of the present work have raised additional, unanticipated questions. The purpose of this section is to highlight some of these lingering and newly identified questions and to guide future research.

Foremost among the more promising avenues of future research is the relationship between thermal features and other techno-subsistence systems, specifically ceramic technology. Thoms (2009) hypothesizes that the arrival of ceramic technology, given the numerous unique and variable cooking functions ceramic vessels can possibly fulfill, would decrease the density of FCR on the landscape (Figure 9-1).

While data on the density of FCR on northern Colorado landscapes is not readily available (an approach more practical on smaller, site-level studies) it is clear that the number of FCR features themselves does anything but decrease during this time. In fact, the majority of FCR features date to this period. However, with the interpretation of FCR features presented here, it is hard to understand how ceramic technology could supplant long-term, med-to-high heating. While geophytic foods could be processed in a ceramic vessel, which would allow a more even distribution of heat, it would still require an open flame (of variable temperature) for an extended period. On the other hand, ceramic vessel processing could readily substitute for any of the open feature processing functions, boiling being the most obvious. As an alternative hypothesis: the introduction of ceramics should not produce noticeable differences in the density of FCR hearth features (or the density of FCR), but should produce noticeable changes in the character of unlined features, as those features are adapted for use with ceramic vessels (potentially manifest as changes in size, shape, and design).

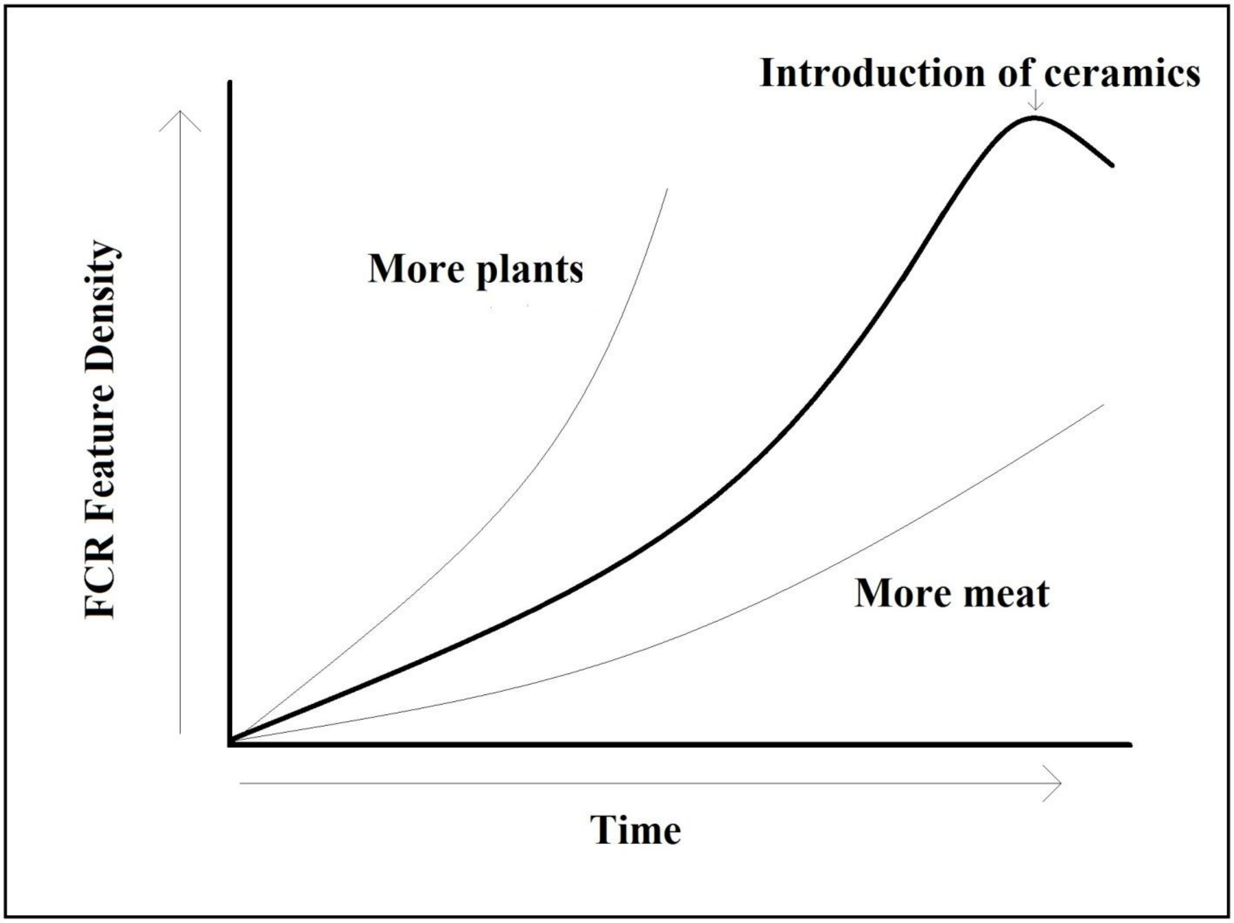


Figure 9-1: Hypothetical model of FCR feature use-intensity and the role of ceramic technology, adapted from Thoms 2009

Recent research has been conducted and aimed to address the question of how much plant material processing one hearth feature represents via experimentation with the thermal breakdown of rock used in thermal feature design (Backhouse and Johnson 2007; Jackson 1998). Preliminary evidence suggests that inferences of feature use intensity and frequency of use based upon the composition of fire-cracked rock assemblages require detailed, local-level experimentation with archaeologically relevant rock types and provides a meaningful avenue for future research. Similar studies may be directed at patterned changes in soil texture, color, and compaction.

Given that the present research suggests parallel changes in feature design and prehistoric subsistence, the most promising research questions will focus on comparison to other fine-grained, local patterns in other subsistence-based technological systems. As Pelton (2013) demonstrates, there are patterns in the extent and intensity of groundstone utilization within high altitude assemblages within the Indian Peaks Wilderness. Given similar hypothesized uses of the fire-cracked rock features and some groundstone types, investigations into the timing and degree of positive correlation between the occurrences of these materials in archaeological assemblages may be particularly fruitful, and add temporal and spatial detail to the inferences presented herein.

Similar approaches are viable for lithic technology, and in the case of lithic projectile distributions, serve as a proxy of alternative subsistence strategies such as large animal procurement. Analysis of the timing of bison and other large animal procurement events (jumps, pounds, drives etc.; Johnston 2013a, 2013b) and intensity of animal resource strategies (limb element representation, degree of bone processing) will also provide a meaningful backdrop for understanding the incorporation of low-ranked plant foods. Additionally, given that plant food and lithic raw material resources are both largely fixed to the landscape and shape landscape use patterns, there may be meaningful correlations between feature use and raw material procurement strategies, and other assemblage dynamics such as the richness and diversity of tool types, and the intensity of tool curation, reuse and rejuvenation; the data presented by Joyner (1983) suggest patterned changes in assemblage dynamics and feature design in the Hanna Basin of Wyoming.

Concluding Remarks: Five Key Points

Lastly, I would like to summarize the preceding research into what I feel are the five key take-away points regarding the type and distribution of thermal features and the ability to draw inferences of past human subsistence behavior from patterns within those feature distributions.

First, present evidence suggests that the climate of the mid Holocene was drier and warmer than preceding periods, beginning around 8000 cal BP, and ameliorated somewhat, sometime around 4500 cal BP (Kay 1998).

Rock-less, or unlined hearths, represent both the earliest and most common features in Northern Colorado. They appear early in the Paleoindian period and persist well into the Protohistoric. On the other hand, rock-inclusive features are temporally and spatially more distinctive; they appear in the lowest parts of the study area at, or very near the beginning of the mid-Holocene drought, or Altithermal, and progress uphill at a rate of around 1000 meters of elevation gain per every 2-3k years.

Rock-inclusive features appear at elevations above 3000 meters only within the last 2000 years or so. Though rock-inclusive hearths are used elsewhere in the study area beginning in the Archaic Period, these early FCR hearth users were not compelled to pursue the same strategies at higher elevations. Given arguments that the highest elevations are effectively drought proof (Benedict and Olson 1978, which seems consistent with the lack of these features at this elevation during documented periods of intense regional drought), the use of these features in the high country within the last 2000 years deserves more consideration. There are apparent changes in the way in which the high country and its resources were incorporated into annual subsistence and mobility strategies. Future research will do well to consider the complex relationships between groundstone, hearth morphology, lithics, and animal control and containment features of the high Rocky Mountains, and the way in which these relationships changed through time.

Regional or landscape level studies of hearth macrobotanical content are currently ill equipped to address questions of subsistence at this scale. The ability to draw meaningful inferences from macrobotanical data is complicated by highly variable preservation conditions within and between areas, differences in analytical strategies between investigators and eras of recording, and a lack of experimental data necessary to address preservation, recovery, and identification of various plant resources. In many cases, we simply do not know what the material signature of a particular resource looks like. Future research should be aimed at identifying alternative analytical methods for the identification of plant resources. In the meantime, macrobotanical data is best used to address the hypothesis outlined herein at the site level, where the variable effect of preservation can be controlled, and the recovery and analysis of features may be standardized across the site.

Lastly, broadly, thermal feature morphology and the role of plant use have been overlooked in favor of larger and more visible evidence of hunting strategies. However, I argue that identifying the timing of rock-inclusive thermal features may help us better understand prehistoric dietary adaptations, their causes and correlations, and how they change through time.

The preceding study aimed to better understand the distribution of hearth feature types throughout Northern Colorado and included nearly 200 radiocarbon dated features from across five counties (really four counties; there are very few dated features in Jackson County). The available evidence suggests that the appearance of diverse feature types has potential climatic impetuses, and correlates with other evidence of changing subsistence strategies. Given the nature of the data set, and the scale at which the investigation was conducted, there are many further refinements possible. Understandably, there are feature sub-types and subtle distinctions between features that are invisible under the taxonomy I developed to address variation at this scale. Additionally, the present study does not probe site-level dynamics, such as functional interconnectedness between multiple features on a single site, the manner of site and feature reuse through time, and the potential for multiple, equally meaningful or important functions of a feature. The patterns described herein hint at the importance of low-ranked plant use at particular points throughout the past, and suggest patterned differences associated with elevation. In the future these ideas must be tested, both at the regional level, as more morphological hearth data are incorporated into the regional dataset, as well as at the local level with site-specific inquires. Ultimately the inferences presented herein will be supported or refuted on a case-by-case basis via comparison to other technological systems, and with more specific, direct subsistence evidence as it becomes available or is more widely produced via increased interest in archaeological plant materials. There are far reaching consequences of intensive, low-ranked plant use on prehistoric mobility, subsistence, and settlement strategies, and a more comprehensive understanding of the prehistoric utilization of past landscapes requires that we recognize the role of plant foods at particular times and places in the past. This work has provided solid evidence to suggest that hearth morphology is one avenue to better understand plant use and by extension, past human behavior.

REFERENCES CITED

Anderson, Jessica E.

2012 Archaeological Investigations of the River Bluffs Open Space, Windsor, Colorado: A Case Study in Cooperation Between Artifact Collectors, the Public, and Archaeologists. Unpublished Master's thesis, Department of Anthropology, Colorado State University, Fort Collins.

Anderson, Cody M.

2010 *Brief Summary report: Feature Salvage and Test Excavation at Site 5WL5588 (CA 3268) Along the Rockies-Express West (Rex-West) Pipeline, Weld County, Colorado (ENSR Report #CR-49)*. Centennial Archaeology Inc. Fort Collins, Colorado for the Department of Energy.

Antevs, Ernst

1955 Geologic-Climatic Dating in the West. *American Antiquity* 20(4):317-335.

Armstrong, David Michael with James P. Fitzgerald and Carron A. Meaney

2010 *Mammals of Colorado*. University Press of Colorado, Denver.

Armstrong, Steven W.

1993 Alder Complex Kitchens: Experimental Replication of Paleoindian Cooking Facilities. *Archaeology in Montana* 34(2):1-66.

Bach, Daniel

2005 Macrofloral and Limited Geomorphological Analysis of 750 Prehistoric Hearths from Southwestern Wyoming. Paper presented at the 7th biennial Rocky Mountain Anthropological Conference, Park City.

Backhouse, Paul N. and Eileene Johnson

2007 Hearth Life: An Experimental Examination of Site-Formation Processes Acting Upon Upland Hunter-Gatherer Camp Site Assemblages on the Southern High Plains. *Plains Anthropologist* 52(202):175-194.

Bamforth, Douglas

2011 Origin Stories, Archaeological Evidence, and Postclovis Paleoindian Bison Hunting on the Great Plains. *American Antiquity* 76(1):24-40.

Beausoleil, Barry

1996 Overlook Site. *Southwestern Lore* 62(3):1-23.

Benedict, James B.

1973 Chronology of Cirque Glaciation, Colorado Front Range. *Journal of Quaternary Research* 3(4):584-599.

1979 Getting away from it all: a study of man, mountains and the two-drought Altithermal.

Southwestern Lore 45:1-12.

1981 *The Fourth of July Valley: Glacial Geology and Archeology on the Timberline Ecotone*. Research Report No. 2, Center for Mountain Archeology. Ward, Colorado.

1985 *Arapaho Pass. Glacial Geology and Archeology at the Crest of the Colorado Front Range*. Research Report No. 3, Center for Mountain Archeology. Ward, Colorado.

1991 *People of the Shining Mountains: High-Altitude Cultural Ecology of the Colorado Front Range*. Center for Mountain Archeology. Ward, Colorado.

1993 *Excavations at Bode's Draw, A Women's Work Area in the Mountains near Estes Park, Colorado*. Research Report No. 6, Center for Mountain Archeology. Ward, Colorado.

1996 *The Game Drives of the Rocky Mountain National Park*. Research Report No. 7, Center for Mountain Archeology. Ward, Colorado.

1998 Archaeological studies in the Devil's Thumb Pass Area, Indian Peaks Wilderness, Summer of 1997. Center for Mountain Archaeology. Prepared for the Arapahoe Roosevelt National Forest, Fort Collins, Colorado. 1999 Effects of changing climate on game-animal and human use of the Colorado high country (USA) since 1000 B.C. *Arctic, Antarctic, and Alpine Research* 31:1-15.

2000 *Game Drives of the Devel's Thumb Pass Area*. In This Land of Shining Moutains: Archaeological Studies in Colorado's Indian Peaks Wilderness Area. E. Steve Cassels (Ed.). Research Report No. 8, Center for Mountain Archaeology. Ward, Colorado.2002 A newly discovered game-drive system in Rocky Mountain National Park, North-Central Colorado. *Southwestern Lore* 68(1):23-37.

2005 Tundra game drives : an Arctic-Alpine comparison. *Arctic, Antarctic, and Alpine Research* 37:425-434.

Benedict, James B.and Byron L. Olson

1978 *The Albion Complex: A Study of Prehistoric Man and the Altithermal.* Research Report No. 1, Center for Mountain Archaeology, Ward, Colorado.

Betancourt, Julio L. with William S. Schuster, Jefery B. Mitton, and R. Scott Anderson

1991 Fossil and Genetic History of a Pinyon Pine (*Pinus Edulis)* Isolate. *Ecology* 72(5):1685-1697.

Bettinger, R. L.

1987 Archaeological approaches to hunter-gatherers. *Annual Review of Anthropology* 16:121-142.

2009 Macroevolutionary Theory and Archaeology: Is There a Big Picture? Springer Press, New York.

Binford, Lewis R.

1978 *Nunamiut ethnoarchaeology*. Academic Press, New York.

1980 Willow Smoke and Dogs' Tails: Hunter Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45(1):4-20.

Boonstra, M. J., J. F. Rijsdijk, C. WSander, E. Kegel, B. Tjeerdsma, H. Militz, J. Van Acker, M. Stevens.

2006a Microstructural and Physical Aspects of Heat Treated Wood. Part 1. Softwoods.

Maderas. Ciencia y tecnología 8(3):193-208.

Boonstra, M. J., J. F. Rijsdijk, C. WSander, E. Kegel, B. Tjeerdsma, H. Militz, J. Van Acker, M. Stevens.
2006b Microstructural and Physical Aspects of Heat Treated Wood. Part 2. Hardwoods. *Maderas. Ciencia y tecnología* 8(3):209-218.

Brechtel, James
2003 *Test Excavations at 5GA1219, Grand County, Colorado*. James Enterprises, Inc. Fort Collins, Colorado.

Brunswig, Robert H.
2001 *Lawn Lake (5LR318): Results of an Archaeological Mitigation Research Project at a High Elevation Prehistoric Site in Rocky Mountain National Park*. Department of Anthropology, University of Northern Colorado. Greely.

Burgess, Robert J.
1981 Cultural Ecological Investigations at the Owl Canyon Rockshelter (5LR104). Unpublished Master's thesis, Department of Anthropology, Colorado State University, Fort Collins.

Byerly, Ryan Michael
2009 Late Pleistocene to Late Holocene Variability in Bison Health: Implications for Human Bison-Based Subsistence on the Northwestern and Central Great Plains. Unpublished Doctoral Dissertation, Department of Anthropology, Southern Methodist University, Dallas.

Byers, David A.
2002 Paleoindian Fat-Seeking Behavior: Evidence from the Hell Gap Site, Locality II Agate Basin Faunal Assemblage. *Plains Anthropologist* 47(183):48-63.

Byers, David A. with Craig S. Smith and Jack M. Broughton
2005 Holocene artiodactyl population histories and large game hunting in the Wyoming Basin, USA. *Journal of Archaeological Science* 32:125-142.

Calhoun, Emily
2011 The Prehistoric Utilization of Mollusc Shell in the Arkansas and South Platte River Basins of Eastern Colorado. Unpublished Master's Thesis, Deaprtment of Anthropology, Colorado State University, Fort Collins.

Cassells, Steve E. and Robert Noel Farrington
1986 Excavations at the Indian Mountain Site, 5BL876: A Multi-Component Stone Circle Site in Colorado's Northeastern Foothills. *Plains Anthropologist* 31(112):129-139.

Chenault, Mark

1999 Introduction. In *Colorado Prehistory: A Context for the Platte River Basin*, edited by Kevin P. Gilmore, Marcia Tate, Mark L. Chenault, Bonnie Clark, Terri McBride, and Margaret Wood, pp. 1–6. Colorado Council of Professional Archaeologists Series. University of Utah Press, Salt Lake City.

1999 Paleoindian Stage. In *Colorado Prehistory: A Context for the Platte River Basin*, edited by Kevin P. Gilmore, Marcia Tate, Mark L. Chenault, Bonnie Clark, Terri McBride, and Margaret Wood, pp. 51-90. Colorado Council of Professional Archaeologists Series. University of Utah Press, Salt Lake City.

Clark, Michele L. and Helen M. Rendell

2003 Late Holocene Dune Accretion and Episodes of Persistent Drought in the Great Plains of Northeastern Colorado. *Quarternary Science Review* 22:1051-1058.

Core, H.A., W.A. Cote and A.C. Day

1979 *Wood Structure and Identification. 2nd Ed.* Syracuse University Press, Syracuse.

Dering, Phil

1999 Earth-Oven Processing in Archaic Period Economies: An Example from a Semi-Arid Savannah in South-Central North America. *American Antiquity* 64(4):659-674.

Doerner, J.

2007 Late Quarternary Prehistoric Environments of the Colorado Front Range. In *Fronteirs in Colorado Paleoindian Archaeology: From the Dent Site to the Rocky Mountains*, edited by R. Brunswig and B. Pitblado, pp. 11-38. University of Colorado, Boulder.

Eighmy, Jeffrey L. and Jason M. LaBelle

1996 Radiocarbon Dating of Twenty-Seven Plains Complexes and Phases. *Plains Anthropologist* 41(155):53-69.

Epis, Rudy C. and Charles E. Chapin

1975 *Geomorphic and Tectonic Implications of the Post-Laramide, Late Eocene Erosion Surface in the Southern Rocky Mountains*. Geological Society of America Memoir 144.

Feiler, Eric

2001 *Archaeological and Geological Investigations at the Willow Bunker Archaeological Area, Pawnee National Grassland, Colorado (1998-1999)*. Research Contribution No. 38 of Paleocultural Research Group.

Fire Ecology in Colorado. Electronic document,

http://csfs.colostate.edu/pdfs/ColoradoFireEcologyOverview101712.pdf, accessed August 2013.

Forman, Steven L. and P. Maat

1990 Stratigraphic Evidence for Late Quarternary Dune Activity Near Hudson on the Piedmont on Northern Colorado. *Geology* 18(8):745-748.

Forman, Steven L. with E. Arthur Bettis III, Timothy J. Kemmis, and Barry B. Miller

1992 Chronological Evidence for Multiple Periods of Loess Deposition During the Late Pleistocene in the Missouri and Missippi River Valley, United States: Implications for the Activity of the Laurentide Ise Sheet. *Palaeogeography, Palaeoclimatology, Palaeoecology* 93(1-2):71-83.

Forman, Steven L., with Robert Oglesby, Vera Markgraf, and Thomas Stafford

1995 Paleoclimatic Significance of Late Quarternary Eolian Deposition on the Piedmont and High Plains, Central United Stated. *Global and Planetary Change* 11(1-2):35-55.

Frison, George C.

1998 Paloeindian Large Mammal Hunters on the Plains of North America. *Proceedings of the National Academy of the Sciences* 95:14576-14583.

Gilmore, Kevin P.

1999 The Late Prehistoric Stage. In *Colorado Prehistory: A Context for the Platte River Basin*, edited by Kevin P. Gilmore, Marcia Tate, Mark L. Chenault, Bonnie Clark, Terri McBride, and Margaret Wood, pp. 175–308. Colorado Council of Professional Archaeologists Series. University of Utah Press, Salt Lake City.

2008 Ritual Landscapes, Population and Changing Sense of Place During the Late Prehistoric Transition in Eastern Colorado. In *Archaeological Landscapes on the High Plains*, edited by Laura L. Scheiber and Bonnie Clark, pp. 71-114. The University Press of Colorado, Boulder.

2009 *Class III Cultural Respurce Inventory of the Rock Creek/Zaharias Property and Results of Phase I and II Evaluative Testing at the Zaharias Site (5BL10853), Boulder County,Colorado*. ERO Resources Corp. for Boulder County Parks and Open Space, Longmont, Colorado.

Gleichman, P.J., C.L. Gleichman and S.L. Karhu

1995 *Excavations at the Rock Creek Site: 1990-1993*. Native Cultural Services, Boulder, Colorado.

Gooding, John D.

1981 *The Archaeology of the Vail Pass Camp*. Highway Salvage Report No. 35

Grant, Marcus P., Christian J. Zeir, and Robert G. Rosenberg

1988 *Cultural Resource Investigations in Stage One Areas of the Basin Study Extension, Cache la Poudre Water and Power Project, Larimer County, Colorado*. Centennial Archaeology, Inc. for the Department of Energy. Fort Collins, Colorado.

Grant, M.P., and R. De Angelo

1998 *Archaeological Excavations of the Button Rock Site (5BL4838) near Lyons, Boulder County, Colorado*. Paragon Archaeological Consultants, Inc. Prepared for the City of Longmont, Colorado.

Harrison, Cheryl A. and Marcia J. Tate

1997 *Evaluative Testing at Site 5JA1068 for the Thompson Land Exchange, Jackson County, Colorado*. Tate and Associates, Inc. Boulder, Colorado.

Hill Jr., with M.G. Hill, and C.C. Widga

2008 Late Quarternary Bison Diminuation on the Great Plains of North America: Evaluating the Role of Human Hunting Versus Climate Change. *Quarternary Science Reviews* 27:1752-1771.

Holliday, Vance T.

1989 Middle Holocene Drought on the Southern High Plains. *Quarternary Research.* 31:74-82.

Jackson, Michael Aaron

1998 The Nature of Fire-Cracked Rock: New Insights From Ethnoarchaeological and Laboratry Experiments. Unpublished Master's Thesis, Department of Anthropology, Texas A&M University, College Station.

Jepson, Daniel A.

1994 *A Cultural Resource Survey Along State Highway 392 at Larimer County Road 3, Larimer County, Colorado*. Report on file at the Office of Archaeology and Historic Preservation, Colorado Historical Society, Denver, Colorado.

Johnson, Ann Mary and Alfred E. Johnson

1998 The Plains Woodland. In *Archaeology of the Great Plains*, edited by W. Raymond Wood, pp. 201-234. University Press of Kansas, Kansas.

Johnson, Ann M. and R.D. Lyons

1997 Bradford House II (5JF51). In *Archaeological Invenstigations at the Ken-Caryl Ranch, Colorado, e*dited by Richard F Somer, pp. 55-92. The Colorado Archaeological Society Memoir No. 6. Denver, Colorado.

Johnston, Christopher M.

2013 Jumping With New Data: Recent Investigations of the Roberts Buffalo Jump (5LR100), Larimer County, Colorado. Paper presented at the 71st Annual Plains Anthropological Conference, Loveland, CO.

Joyner, Kathryn Lynne

1983 An Investigation of Prehistoric Fire Pits Within the Hanna Basin, South-Central Wyoming. Unpublished Master's thesis, Department of Anthropology, University of Colorado, Boulder.

Kainer, R.K.

1976 Archaeological Investigations or the Spring Gulch Site (5LR252). Unpublished Master's thesis, Department of Anthropology, Colorado State University, Fort Collins.

Kalasz, S.M., C.J. Zier, D.A. Jepson, M. McFaul, W. Doering, and M.A. Van Ness
1992 *Archaeological Excavation of the Cass Site (5WL1483), Weld County, Colorado*. Centennial Archaeology, Inc. Submitted to the Archaeological Unit, Colorado Department of Transportation, Denver.

Kalasz, Stephen M., and Christian J. Zeir
1993 *The Cass Archaeology Site and Northern Colorado Prehistory*. Centennial Archaeology Inc., for the Colorado Department of Transportation. Fort Collins, Colorado.

Kay, Marvin
1998 The Great Plains Setting. In *Archaeology on the Great Plains*, Edited by W. Raymond Wood, pp. 16-47, University of Kansas Press, Lawrence.

Kelly, Robert L.
1995 *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Smithsonain Institution Press, Washington.

Kelly, Robert. L. & L. C. Todd.
1988. Coming to the Country: Early Paleoindian Hunting and Mobility. American Antiquity 53(2):231-244.
Kindig, Jean M.
2000 *Two Ceramic Sites in the Devil's Thumb Valley*. In This Land of Shining Mountains, edited by E. Steve Cassells, pp. 95-123. Center for Mountain Archeology, Research Report No. 8. Ward, Colorado.

Kornfeld, Marcel with George C. Frison and Mary Lou Larson
2010 *Prehistoric Hunter-Gatherers of the High Plains and Rockies*. Left Coast Press, Walnut Creek.

Kuznar, Lawrence A.
1993 Mutulaism Between *Chenopodium*, Herd Animals, and Herders in the South Central Andes. *Mountain Research and Development* 13(3):257-265.

LaBelle, Jason Mitchel
2005 Hunter-Gatherer Foraging Variability During the Early Holocene of the Central Plains of North America. Unpublished Doctoral Dissertation, Department of Anthropology, Southern Methodist University, Dallas.

LaBelle, Jason M. and Brian N. Andrews
2007 *Class II Archaeological Survey of the Soapstone Prairie Natural Area, Larimer County, Colorado*. LOPA Archaeology Report 07-02. Department of Anthropology, Colorado State University. Fort Collins, Colorado.

LaBelle, Jason M., with Brian N. Anderws and Cody C. Newton

2007 *Class II Archaeological Survey of the Red Mountain Ranch Open Space, Larimer County, Colorado*. LOPA Archaeology Report 07-01. Department of Anthropology, Colorado State University. Fort Collins, Colorado.

LaBelle, Jason M. and Jason W. Bush
2007 *Class II Archaeological Survey of the Red Mountain Open Space, Larimer County, Colorado*. LOPA Archaeological Report 09-02. Department of Anthropology, Colorado State University. Fort Collins, Colorado.

LaBelle, J.M. and S.R. Pelton
2013 Cummunal Hunting along the Continental Divide of Northern Colorado: Results from the Olson Game Drive (5BL147), USA. *Quaternary International* 297:45-63.

Larson, R.M., with L.C. Todd, E.K. Kelly, and J.M. Welker
2001 Carbon stable isotopic analysis of bison dentition. *Great Plains Research* 11:25–64.

Lawrence, Bob and Cheryl Muceus
1980 *Preliminary Report of Test Excavations at 5WL.453 Near Johnestown*. Report on file, Office of Archaeology and Historic Preservation, Denver.

Liestman, Terri L.
1984 *Archaeological Excavations at the Pontiac Pit Site: A Multi-component Campsite in the Rocky Mountains*. Midwest Archeological Center. Lincoln, Nebraska.

Leyden, Jeremy J., and Gerald A. Oetelaar
2001 Carbon and Nitrogen Isotopes in Archaeological Bison Remains as Indicators of Paleoenvironmental Change in Southern Alberta. *Great Plains Research* 11(1):3-24.

Long, Jennifer
2011 An Analysis of Stone Circle Site Structure on the Pawnee National Grassland, Weld County, Colorado. Unpublished Master's Thesis, Deaprtment of Anthropology, Colorado State University, Fort Collins.

Lowe, James A.
2003 *Testing Results at Sites 5GA120, 5GA130, 5GA669, 5GA2049, 5GA2051, 5GA2054, and 5GA2055 within the proposed Windy Gap/Gore Canyon Ranch/Bureau of Land Management Land Exchange, Grand County, Colorado*. James Enterprises, Inc. Fort Collins, Colorado.

Mark, Robert F. with Cody M. Anderson, Christianm J. Zeir, and Denise Fallon Zeir
2009 *Results of Archaeological Monitoring for the Rockies Express-West (Rex-West) Pipeline Project in Northeastern Colorado, Southern Wyoming and the Nebraska Panhandle*. Centennial Archaeology, Inc. for the Dapartment of Energy. Fort Collins, Colorado.

Madole, R.F.
1994 Stratigarphic Evidence of Deserification in the West-Central Great Plains Within the Past 1000 yr. *Geology* 22:483-486.
1995 Spatial and Temporal Patterns of Late Quaternary Eolian Deposition, Eastern Colorado, U.S.A. *Quaternary Science Reviews* 14:155-177.

Meltzer, David J.
1991 Altithermal Archaeology and Paleoecology at Mustang Springs, on the Southern High Plains of Texas. *American Antiquity* 56(2):236-267.

Meltzer, David J., and Michael B. Collins
1987 Prehistoric Water Wells on the Southern High Plains: Clues to Altithermal Climate. *Journal of Field Archaeology* 14(1):9-28.

Metcalf, Michael D. and Kevin D. Black
1999 *Archaeological Excavations at the Yarmony Pit House Site, Eagle County, Colorado*. BLM Cultural Resource Series, Number 31. Kremling, Colorado.

Morris, E.A., K. L. Kvamme, N.T. Ohr, M.D.Metcalf, H.M. Davidson
1979 *Archaeology of the Boxelder Project: A Water Control Project in Larimer County North Central Colorado, 1972-1979*. Report on file, Office of Archaeology and Historic Preservation, Denver.

Morris, E.A., and W.J. Litzinger
1985 *Analysis of Floor Samples from a Hogback Phase, Early Ceramic Period, House at the Kinney Springs Site (5LR144C), North-Central Colorado*. Abstracts of Papers, p. 115, 50th Annual Meeting of the Society of American Archaeology, Denver.

Morris, E.A., and J.R. Marcotte
1976 *Archaeological Investigations on the Joe Wright Reservoir Project, a High Altitude Locality in Northern Colorado*. Laboratory of Public Archaeology Cultural resource Management report 7, Colorado State University. Fort Collins, Colorado.

Muhs, Daniel R.
1985 Age and Paleoclimatic Significance of Holocene Dune Sand in Northeastern Colorado. *Annals of the Association of American Geographers* 75(4):566-582.

Muhs, Daniel R., John N. Aleinikiff, Thomas W. Stafford, Jr, Rolf Kihl, Josh Been, Shannnon A. Mahan and Scott Cowherd
1999 Late Quaternary loess in northeastern Colorado: Part I—Age and paleoclimatic significance. *Geological Society of Ammerica Bulletin* 111(12):1861-1875.

Muhs, D.R., Stafford, T.W., Cowherd, S.D., Mahan, S.A., Kihl, R., Maat, P.B., Bush, C.A., and Nehring, J.
1996 Origin of the late Quaternary dune fields of northeastern Colorado: *Geomorphology* 17:129-149.

Muhs, D.R., Stafford, T.W., Jr., Swinehart, J.B., Cowherd, S.D., Mahan, S.A., Bush, C.A., Madole, R.F., and Maat, P.B.
1997 Late Holocene eolian activity in the mineralogically mature Nebraska Sand Hills: *Quaternary Research* 48:162-176.

Muhs, D.R., and Maat, P.B.
1993 The potential response of eolian sands to greenhouse warming and precipitation reduction on the Great Plains of the U.S.A. *Journal of Arid Environments* 25:351 361.

O'Brien, M. J. with T. D. Holland, R. J. Hoard, and G. L. Fox
1994 Evolutionary implications of design and performance characteristics of prehistoric pottery. *Journal of Archaeological Method and Theory* 1:259–304.

O'Neil, Brian
2002 *Salvage Data Recovery of Sites 5GA2524 an 5GA2526 on Grazing Lease Allotment 7505, Lower Sulphur Gulch, in Middle Park, Grand County, Colorado*. Bureau of Land Management. Kremmling Field Office.

Ohr, N., K.L. Kvamme, and E.A. Morris
1979 *The Lykins Valley Site (5LR263): A Stratified Locality on Box Elder Creek, Larimer County, Colorado*. Submitted to the U.S. Department of Interior. Ms. on file athe the office of Archaeology and Historic Preservation.

Painter, Mary W., Christian J. Zier, Daniel A. Jepson, Michael McFaul, Karen Lynn Traugh and Grant D. Smith
1995 *Archaeological and Geomorphic Investigations along U.S. Highway 34 between Kersey and Hardin, Weld County, Colorado*. Centennial Archaeology, Inc., Fort Collins, Colorado and Laramie Soils Servic, Laramie, Wyoming.

Pagoulatos, P.
1992 The Re-Use of Thermally Altered Stone. *North American Archaeologist* 13: 115-129.

Parks, Erin M. and Jason M. LaBelle
2008 *Class II Archaeological Survey of the Soapstone Prairie Natural Area and Associated Access Roads, Larimer County, Colorado*. LOPA Archaeology Report 08-03.Department of Anthropology, Colorado State University. Fort Collins, Colorado.

Pearsall, Deborah M.
2000 *Paleoethnobotany: A Handbook of Procedures.* Academic Press, Massachusetts.

Pelton, Spencer
2012 Old Rocks, New Approach: A Regional Scale Analysis of Ground Stone Tools from the Colorado Front Range High Country. Paper presented at the 71st Plains Anthropological Conference, Loveland.

Piperno, Dolores R., Anthony J. Ranere, Irene Holst, Jose Iriarte, and Ruth Dickau
2009 Starch Grain and Phytolith Evidence for Early Ninth Millenium B.P. Maize from the Central Balsas River Valley, Mexico. *Proceedings of the National Academy of Sciences* 106:5019-5024.

Radiocarbon Database Project
2011 Dominguez Archaeological Research Group, Inc. RCGraph Version 3.2.1. December 11, 2011.

Reasoner, M.A., and Jodry, M.A.
2000 Rapid response of alpine timberline vegetation to the Younger Dryas climate oscillation in the Colorado Rocky Mountains, USA. *Geology* 28:51–54.

Renfrew, Colin and Paul Bahn
2004 *Archaeology: Theories, Methods, and Practice.* Thames and Hudson, New York.

Reust, Thomas P. and Jeff S. Johnson
1998 Archaeology of the Horn Ranch Site. TRC Mariah Associates, Inc. Laramie, Wyoming.

Slessman, Scott A., John D. Kennedy, Kelly A. Stroden, Christopher C. Kinneer, and Stephen M. Kalasz.
2002 Report prepared by Centennial Archaeology, Inc., Fort Collins. Submitted to the Colorado Department of Transportation. Denver, Colorado.

Smith, Bruce D. and C. Wesley Cowan
1987 Domesticated Chenopodium in Prehistoric Eastern North America: New Accelerator Dates from Eastern Kentucky. *American Antiquity* 52(2):355-357.

Smith, Christy J.
2003 *Test Excavations at Cultural Sites 5GA2826 and 5GA2827 Grand County, Colorado*. Bureau of Land Management, Kremmling Field Office.

Smith, Craig S. and Lance M. McNees
1999 Facilities and Hunter-Gatherer Long-Term Land Use Patterns: An Example from Southwest Wyoming. *American Antiquity* 64(1):117-136.
2005 *Cymopterus bulbosus* and Prehistoric Foragers: Patch Size, Plant Density and Return Rates. *Journal of Ethnobiology* 25(1):1-23.

Smith, Eric Alden
1983 Anthropological Applications of Optimal Foraging Theory: A Critical Review. *Current Anthropology* 24(5):625-651.
2000 Three Styles in the Evolutionary Study of Human Behavior. In *Human Behavior and Adaptation*: *An Anthropological Perspective,* edited by Lee Cronk, William Irons, and Napoleon Chagnon, pp 27-46. London.

Smith, Eric Alden, and Bruce Winterhalder
1985 On the Logic and Application of Optimal Foraging Theory: A Brief Reply to Martin. *American Anthropologist* 87(3):645-648.

Smith, Craig S. with W. Martin, and K.A.Johansen
2001 Sego Lillies and Prehistoric Foragers: Return Rates, Pit Ovens, and Carbohydrates. *Journal of Archaeological Science* 28(2):169-184.

Stiger, Mark
2001 *Hunter-Gatherer Archaeology of the Colorado High Country*. University Press of Colorado, Boulder.

Surovell, Todd A. with Judson Byrd Finley, Geoffrey M. Smith, P. Jeffrey Brantingham, and Robert Kelly
2009 Correcting Temporal Frequency Distributions for Taphonomic Bias. *Jouranl of Archaeological Science* 36(8):1715-1724.

Surovell, T.A. and N.M. Waguespack
2007 Folsom Hearth-Centered Use of Space at the Barger Gulch, Locality B. In *Emerging Frontiers in Colorado Paleoindian Arcaheology,* edited by R.S. Brunswig and B. Pitblado, pp. 219-259, University of Colorado Press, Boulder.

Tate, Marsha J.
1999 Archaic Stage. In *Colorado Prehistory: a Context for the Platte River Basin,* edited by Kevin P. Gilmore, Marcia Tate, Mark L. Chenault, Bonnie Clark, Terri McBride, and Margaret Wood, pp. 91-174. Colorado Council of Professional Archaeologists Series. University of Utah Press, Salt Lake City.

Thompson, Kevin W.
1986 Pheobe Rockshelter: A Multi-Component Site in North-Central Colorado. Unpublished Master's Thesis, Department of Anthropology, Colorado State University, Fort Collins.

Thoms, A.V
2008a The fire stones carry: Ethnographic records and archaeological expectations for hot-rock cookery in western North America. *Journal of Anthropological Archaeology* 27(4):443-460.
2008b Ancient Roots of Carbohydrate Revolutions in South-Central North America. *Plains Anthropologist* 53(205):121-136.
2009 Rocks of ages: propagation of hot-rock cookery in western North America. *Journal of Archaeological Science* 36(3):573-591.

Troyer, Michael D.
2012a 38 Years Later: 5LR110 and Red Mountain Archaeology. Paper presented at the 34th Annual Meeting of the Colorado Council of Professional Archaeologists, Durango

USDA Plants Database. Electronic document, http://plants.usda.gov/java/, accessed August 2013

Vandorpe, Patricia, and Stefanie Jacomet
2007 Comparing different pre-treatment methods for strongly compacted organic sediments prior to wet-sieving: a case study on Roman waterlogged deposits. *Environmental Archaeology* 12(2):207-214.

Wageuspack, N.M. and T.A. Surovell
2003 Clovis Hunting Strategies, or How to Make Out on Plentiful Resources. *American Antiquity* 68:333-352.

Wagner, Gail
1982 Testing Floatation Recovery Rates. *American Antiquity* 47:127-132.

Wandsnider, LuAnn
1997 The Roasted and the Boiled: Food Composition and Heat Treatment with Special Emphasis on Pit-Hearth Cooking. *Journal of Anthropological Archaeology* 16(1):1-48.

Weber, William Alfred and Ronald C. Wittmann
1992 *Catalog of the Colorado Flora: a Biodiversity Baseline.* University Press of Colorado, Boulder

Wheeler, Charles W. and Michael L. Burney
1984 *Windy Gap: Aboriginal Adaptation to Middle Park, Grand County, Colorado*. Report prepared by Western Cultural Resource Management for the Northern Colorado Water Conservancy District. Denver, Colorado.

Winterhalder, B.
1980 Foraging strategy adaptations o fboreal forest Cree. *American Journal of Physical Anthropology* 52(2):293-293.
1983 Opportunity Cost Foraging Models for Stationary and Mobile Predators. *The American Naturalist* 122:73-84.
1986 Diet Choice, Risk, and Food Sharing in a Stochastic Environment. *Journal of Anthropological Archaeology* 5:369-392.
2001 The behavioural ecology of hunter-gatherers. In *Hunter-Gatherers: An Interdisciplinary Perspective*, edited by C. PanterBrick, R.H. Layton, and P. Rowley Conwy, pp. 12-38. Biosocial Society Series, Cambridge Univ Press, Cambridge.

Winterhalder, Bruce, and Douglas J. Kennett
2009 Four Neglected Concepts with a Role to Play in Explaining the Origins of Agriculture. *Current Anthropology* 50(5):645-648.

Winterhalder, B., and E. A. Smith
2000 Analyzing adaptive strategies: Human behavioral ecology at twenty-five. *Evolutionary Anthropology* 9(2):51-72.

Wood, Raymond
1967 Archaeological Investigations of Northeastern Colorado. Unpublished Ph.D Dissertation, University of Colorado, Boulder.

Wright, Karen I.
2005 The Emergence of Cooking in Western Asia. *Archaeology International* 2004-2005:33-37.

Appendix A – Hearth Data

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5BL67	Hungry Whistler	1	1	75	48	61.5	23	I-9777	4010	90			Benedict 1991
5BL69	Scratching Deer		1	70	55	62.5	6	I-3265	1260	95			Benedict 1991
5BL70		A	1	75	45	60	13	I-3023	5650	145		Abies sp. and Picea sp.	Benedict 1978
5BL70		B	1	45	30	37.5	15	I-4419	5350	130			Benedict 1978
5BL70		C	1	50	50	50	Unk	I-3266	7650	190			Benedict 1978
5BL94	Coney Lake	A	1	55	43	49	25	I-15,134	3660	130		Coniferae sp. and Salix sp.	Benedict 1990
5BL94	Coney Lake	B	1	47	47	47	10	I-15, 132	1360	80			Benedict 1990
5BL94	Coney Lake	C	1	53	32	42.5	12	I-6775	1805	90			Benedict 1990
5BL94	Coney Lake	D	2	46	33	39.5	6.5	I-15, 133	1210	80			Benedict 1990
5BL94	Coney Lake	E	2	32	28	30	9	I-12, 301	1430	80			Benedict 1990
5BL94	Coney Lake	F	2	59	46	52.5	20	I-6776	1200	90			Benedict 1990
5BL94	Coney Lake	G	1	65	55	60	6	I-6774	1585	90			Benedict 1990
5BL94	Coney Lake	H	1	33	33	33	16	BETA-23738	5710	115			Benedict 1990

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5BL102	Devils Thumb Hearth Site	A	2	50	50	50	4	BETA-74906	250	60			Kindig 2000
5BL120	Fourth of July Valley	2S/2W	1	44	33	38.5	9	I-6544	5880	120			Benedict 1981
5BL153		1	2	59	55	57	11	BETA-56282	855	55	Abies sp., Picea sp., Coniferae sp., Fragaria sp., and Juniperus sp.		Benedict 2000
5BL153		2	2	72	63	67.5	12	BETA-57247	975	55	Abies sp., Picea sp., Coniferae sp., Fragaria sp., and Juniperus sp.		Benedict 2000
5BL153		3	1	60	45	52.5	3	BETA-65656	3020	55	Picea sp., Abies sp., Chenopodium sp., Poaceae sp., and Polygonum sp.		Benedict 2000
5BL153		4	1	45	26	35.5	7	BETA-65657	1875	55	Picea sp., Abies sp., Chenopodium sp., Poaceae sp., and Polygonum sp.	Picea sp.	Benedict 2000
5BL153		6	2	81	56	68.5	4	BETA-65658	985	55	Abies sp. and Picea sp.		Benedict 2000
5BL170	Ptarmigan	1	1	Unk	Unk	Unk	Unk	I-7458	6450	110			Benedict 1981

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5BL876	Indian Mountain	1	Unk	Unk	Unk	Unk	Unk	AA-461	1280	195			Cassells and Farrington 1986
5BL876	Indian Mountain	3	Unk	Unk	Unk	Unk	Unk	AA-354	1120	200			Cassells and Farrington 1986
5BL2712	Rock Creek	1	1	56	50	53	13	BETA-40187	850	70			Gleichman et al. 1995
5BL2712	Rock Creek	7	1	40	46	43	19	BETA-40188	970	70			Gleichman et al. 1995
5BL2712	Rock Creek	11	1	50	45	47.5	25	BETA-71549	1080	70			Gleichman et al. 1995
5BL2712	Rock Creek	14	1	56	56	56	31	BETA-68171	920	60			Gleichman et al. 1995
5BL2712	Rock Creek	16	1	50	50	50	20	BETA-68169	930	70			Gleichman et al. 1995
5BL2712	Rock Creek	17	1	52	47	49.5	23	BETA-68170	960	70			Gleichman et al. 1995
5BL2712	Rock Creek	20	1	54	51	52.5	16	BETA-71550	3120	190			Gleichman et al. 1995
5BL2712	Rock Creek	22	1	47	45	46	13	BETA-68172	3000	190			Gleichman et al. 1995
5BL2712	Rock Creek	29	1	48	41	44.5	3	BETA-71550	1100	100			Gleichman et al. 1995
5BL2712	Rock Creek	34	1	49	Unk	49	14	TX-8922	5490	62			Gleichman et al. 1995
5BL2712	Rock Creek	12	3	50	Unk	50	27	BETA-58396	6240	190			Gleichman et al. 1995
5BL3440	Devils Thumb Game Drive Site	1	1	40	30	35	8	BETA-79098	2250	70		Abies Lasiocarpa	Benedict 2000

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5BL3440	Devils Thumb Game Drive Site	NA	1	60	60	60	11	BETA-54909/68389	765	55			Benedict 1998
5BL4838		1	Unk	Unk	Unk	Unk	Unk	B-121877	3380	120		Pinus sp.	Grant and De Angelo 1998
5BL4838		2	Unk	Unk	Unk	Unk	Unk	B-121878	3450	60		Pinus sp.	Grant and De Angelo 1998
5BL10853		1	2	60	60	60	Unk	BETA-256863	1120	50		Populus sp. and Salix sp.	Gilmore et al. 2009
5BL10853		3	2	60	42	51	20	BETA-256864	1290	40		Populus sp. and Salix sp.	Gilmore et al. 2009
5GA21		A1	1	32	25	28.5	10.5	I-5449	8460	140			Smith 2000
5GA22	Caribou Lake	A2	1	56	37	46.5	7	I-5451	1400	95			Benedict 1985
5GA22	Caribou Lake	A3	1	41	33	37	0	I-5450	765	90			Benedict 1985
5GA22	Caribou Lake	A4	1	80	80	80	7	AA-21984/26255	7955	75		Abies sp.	Benedict 1985
5GA22	Caribou Lake	B1	2	65	45	55	7	I-12391	1750	80			Benedict 1985
5GA22	Caribou Lake	B2	2	44	43	43.5	10	I-6480	785	90			Benedict 1985
5GA22	Caribou Lake	B3	2	45	41	43	7	I-12390	1930	80			Benedict 1985
5GA22	Caribou Lake	B4	1	Unk	Unk	Unk	8	I-6481	1515	90			Benedict 1985
5GA22	Caribou Lake	C1	2	35	30	32.5	15	I-6482	1240	90			Benedict 1985

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5GA128		2	1	Unk	Unk	Unk	33	BETA 2975	7280	80			Wheeler and Burney 1984
5GA128		7	3	35	Unk	35	30	BETA-5995	5500	70			Wheeler and Burney 1984
5GA130		1	Unk	Unk	Unk	Unk	Unk	BETA-187017	2880	50			Lowe 2003
5GA151	Granby	2	1	70	70	70	25	BETA-3419	1560	70			Wheeler and Burney 1984
5GA151	Granby	4	1	80	80	80	20	BETA-3668	360	70			Wheeler and Burney 1984
5GA151	Granby	5	1	45	45	45	25	BETA-2976	7170	200			Wheeler and Burney 1984
5GA151	Granby	7	1	160	80	120	Unk	BETA-3775	4430	70			Wheeler and Burney 1984
5GA151	Granby	20	1	20	20	20	6	UNK	8730	140			Wheeler and Burney 1984
5GA151	Granby	21	1	20	20	20	15	BETA-4706	3840	90			Wheeler and Burney 1984
5GA151	Granby	23	2	100	70	85	5	UNK	1450	60			Wheeler and Burney 1984
5GA151	Granby	25	1	200	80	140	45	BETA-5136	3170	70			Wheeler and Burney 1984
5GA151	Granby	29	2	80	70	75	20	BETA-3774	1450	60			Wheeler and Burney 1984
5GA151	Granby	40	2	50	50	50	20	BETA-4949	1555	200			Wheeler and Burney 1984
5GA151	Granby	41	1	110	70	90	40	BETA-4944	6140	140			Wheeler and Burney 1984
5GA151	Granby	46	1	15	15	15	3	BETA-4705	8730	140			Wheeler and Burney 1984
5GA151	Granby	52	1	30	30	30	35	BETA-4948	6100	125			Wheeler and Burney 1984

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5GA151	Granby	55	1	65	65	65	25	UNK-107	3570	60			Wheeler and Burney 1984
5GA151	Granby	53-1	1	25	25	25	15	BETA-4945	3775	165			Wheeler and Burney 1984
5GA151	Granby	53-3	1	80	80	80	20	BETA-4947	2780	120			Wheeler and Burney 1984
5GA217	Pontiac Pit	5	2	78	78	78	14	BETA6880	810	50			Liestman 1984
5GA217	Pontiac Pit	9	2	58	58	58	17	BETA-6881	2920	50			Liestman 1984
5GA217	Pontiac Pit	11	2	70	40	55	25	BETA-6882	4710	120			Liestman 1984
5GA217	Pontiac Pit	12	2	68	68	68	12	BETA-6883	890	50			Liestman 1984
5GA217	Pontiac Pit	13	2	65	60	62.5	10	BETA-7209	3230	50			Liestman 1984
5GA217	Pontiac Pit	16	2	50	60	55	25	BETA-7210	980	180			Liestman 1984
5GA217	Pontiac Pit	17	2	30	30	30	12	BETA-7202	3920	160			Liestman 1984
5GA217	Pontiac Pit	18	2	50	50	50	10	BETA-7203	2410	540			Liestman 1984
5GA217	Pontiac Pit	19	2	50	50	50	12	BETA 7206	4070	170			Liestman 1984
5GA222		1	3	Unk	Unk	Unk	26	BETA-6878	780	50			Benedict 1985
5GA670		3	1	85	50	67.5	20	BETA 2973	7400	190			Wheeler and Burney 1984
5GA672		2	2	Unk	Unk	Unk	65	BETA-2974	5290	100			Wheeler and Burney 1984
5GA696		1	2	18	Unk	18	10	UGA-4498	995	80			Wheeler and Burney 1984

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5GA698		1	1	40	40	40	Unk	UGA-4499	775	75			Wheeler and Burney 1984
5GA700		1	1	Unk	Unk	Unk	3	UGA-4500	1450	295			Wheeler and Burney 1984
5GA869	Benchmark	II-N-10	1	40	32	38	7	BETA-118774	770	80			Reust and Johnson 1998
5GA869	Benchmark	II-N-A	2	75	75	75	13	BETA-84866	800	50	Unk Seed		Reust and Johnson 1998
5GA869	Benchmark	II-S-1	2	99	88	96	20	BETA-110881	340	60			Reust and Johnson 1998
5GA869	Benchmark	II-S-8	2	97	91	94	28	BETA-110878	920	50			Reust and Johnson 1998
5GA869	Benchmark	I-S-5	1	53	44	49	6	BETA-113177	6500	50			Reust and Johnson 1998
5GA869	Benchmark	I-S-6	1	42	40	41	22	BETA-110879	6910	60			Reust and Johnson 1998
5GA1190		2	1	50	50	50	17	BETA 120984	7040	70			Harrison and Tate 1997
5GA1190		2	1	24	17	20.5	17	BETA 120983	6640	120			Harrison and Tate 1997
5GA1219		1	2	Unk	Unk	Unk	Unk	SR-6191	4450	40			Brechtel 2003
5GA1494		2	1	Unk	Unk	Unk	Unk	BETA-39160	1095	60			Unpublished
5GA1495		1	1	Unk	Unk	Unk	Unk	BETA-39159	1530	60			Unpublished
5GA2524		1	2	126	120	123	20	BETA-147164	1640	80		Juniperus sp.	Radiocarbon Database
5GA2526		1	2	100	60	80	5	BETA-162584	4150	40			O'Neil 2002
5GA2827		1	2	Unk	Unk	Unk	Unk	BETA-181388	2820	60			Smith 2003

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5GA2912		1	2	Unk	Unk	Unk	Unk	BETA-179556	450	70			O'Neil 2003
5JA421	Sue	5	2	Unk	Unk	Unk	Unk	BETA-285032	800	40			Radiocarbon Database
5JA1068		2	Unk	Unk	Unk	Unk	Unk	BETA-110839	1530	100			Harrison and Tate 1997
5LR13	Lindenmeier	3	Unk	Unk	Unk	Unk	Unk	BETA-42999	5280	80		Pinus sp.	Jones 1995
5LR104	Owl Canyon Rockshelter	1	2	70	60	65	22	UGA 1349	1280	80		Pinus Edulis and Juniperus sp.	Burgess 1981
5LR104	Owl Canyon Rockshelter	11	3	60	55	57.5	35	UGA 1350	930	60		Pinus Edulis and Juniperus sp.	Burgess 1981
5LR104	Owl Canyon Rockshelter	18	2	50	45	47.5	9	UGA 1351	1005	60		Juniperus sp. and Pinus Contorta	Burgess 1981
5LR110	Line Shack	CA-TF-1	1	Unk	56	56	20	BETA-265328	6220	50			CMPA
5LR110	Line Shack	EA-TF-1	2	Unk	75	75	38	BETA-265327	1270	40			CMPA
5LR110	Line Shack	EA-TF-2	2	Unk	64	64	13	UGA-10290	1110	25			CMPA

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5LR144	Kinney Springs	4	Unk	Unk	Unk	Unk	Unk	BETA-7328	1510	70			Morris and Litzinger 1985
5LR144	Kinney Springs	30	Unk	Unk	Unk	Unk	Unk	BETA-10196	950	60			Morris and Litzinger 1985
5LR144	Kinney Springs	C	Unk	Unk	Unk	Unk	Unk	BETA-5126	1600	100			Morris and Litzinger 1985
5LR161	Phoebe Rockshelter	14	1	110	95	102.5	20	BETA-3869	3570	60	Chenopodium sp.	Juniperus sp.	Thompson 1986
5LR220	Joe Wright	1	2	Unk	Unk	Unk	Unk	UGA-1387	1690	70			Morris 1976
5LR220	Joe Wright		Unk	Unk	Unk	Unk	Unk	UGA-1467	2000	60			Morris 1976
5LR252	Spring Gulch	2	2	91	62	76.5	31	UGA-673	1705	70		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	5	2	91	62	76.5	31	UGA-670	1315	70		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	6	2	75	54	64.5	10	UGA-664	1075	135		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	7	2	91	62	76.5	31	UGA-669	2340	85		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	8	2	75	54	64.5	10	UGA-672	3095	75		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	10	2	75	54	64.5	10	UGA-829	2415	85		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	18	2	75	54	64.5	10	UGA-1049	1485	130		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	21	2	75	54	64.5	10	UGA-1050	935	140		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	29	2	75	54	64.5	10	UGA-1048	3855	350		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	33	2	91	62	76.5	31	UGA-1047	3700	105		Cercocarpus Montanus	Kainer 1976

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5LR252	Spring Gulch	44	2	75	54	64.5	10	UGA-1051	880	180		Cercocarpus Montanus	Kainer 1976
5LR252	Spring Gulch	10a	3	52	46	49	18	UGA-671	2830	135		Cercocarpus Montanus	Kainer 1976
5LR263	Lykins Valley	NA-1	1	Unk	Unk	Unk	Unk	UGA-816	250	85			Ohr, Kvamme, and Morris 1979
5LR263	Lykins Valley	NA-3	1	Unk	Unk	Unk	Unk	UGA-813	210	95			Ohr, Kvamme, and Morris 1979
5LR263	Lykins Valley	NA-4	1	Unk	Unk	Unk	Unk	UGA-814	420	80			Ohr, Kvamme, and Morris 1979
5LR263	Lykins Valley	NA-6	1	Unk	Unk	Unk	Unk	UGA-812	1370	175			Ohr, Kvamme, and Morris 1979
5LR263	Lykins Valley	NA-7	2	Unk	Unk	Unk	Unk	UGA-818	1675	85			Ohr, Kvamme, and Morris 1979
5LR284	Lightning Hill	3	Unk	Unk	Unk	Unk	Unk	BETA-1389	1635	160			Morris and Marcotte 1977
5LR1062	Overlook	B	1	50	35	42.5	7	BETA 54730	410	60			Beausoleil 1996
5LR1098		5	1	60	52	56	15	BETA 120985	6960	80			Grant et al. 1988
5LR1098		12	2	170	170	170	8	BETA-23490	570	60			Grant et al. 1988
5LR1098		15	2	110	80	95	10	BETA-23941	1080	80	Chenopodium sp. and Argemone sp.		Grant et al. 1988
5LR1370	Bode's Draw	1	2	140	140	140	25	I-15, 135	910	80	Pseudotsuga Menziesii and Pinus Contorta		Benedict 1993

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5LR1370	Bode's Draw	2	3	110	120	115	32	I-15, 952	2270	80		Coniferae sp.	Benedict 1993
5LR1370	Bode's Draw	3	1	30	22	26	13.5	I-15, 953	820	80	Arctostaphylos uva-ursi	Pseudotsuga Menziesii and Pinus contorta	Benedict 1993
5LR9991		1	1	54	51	52.5	16	BETA 156459	1160	60	Oryzopsis Hymenoides	Atriplex sp. and Sacrobatus sp.	Slessman and Kennedy 2002
5LR9991		4	2	51	45	48	6	BETA-156461	1960	40			Slessman and Kennedy 2002
5LR9991		11	1	71	68	69.5	37	BETA-156462	2540	60		Atriplex sp. and Sacrobatus sp.	Slessman and Kennedy 2002
5LR9991		12	1	15	12	13.5	8	BETA-156463	2660	60		Atriplex sp.	Slessman and Kennedy 2002
5LR9991		13	1	16	16	16	7.5	BETA-156464	243	50		Atriplex sp. and Sacrobatus sp.	Slessman and Kennedy 2002
5LR10243			1	Unk	Unk	Unk	Unk	UNK	1100	40			Brunswig 2001
5LR11569	Boxelder Arroyo	1	1	50	Unk	50	18	BETA-247835	660	40			CMPA
5LR11585	Howling Beast	TF 1-1	1	Unk	Unk	Unk	Unk	UGAMS-10285	1190	25		Pinus Contorta	CMPA
5LR11585	Howling Beast	TF 2-1	2	Unk	Unk	Unk	Unk	UGAMS-10286	2660	25		Pinus Contorta	CMPA
5LR11585	Howling Beast	TF-3-3	2	108	Unk	108	19	UGAMS-10287	1480	25		Juniperus sp.	CMPA

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5LR11711	Second Arroyo	TF-4	1	Unk	Unk	Unk	Unk	UGA-10284	1950	25		Atriplex sp./Sacrobatus sp.	CMPA
5LR11718	Black Shale Arroyo	6	2	60	60	60	20	BETA-287894	1270	40		Atriplex sp. or Sacrobatus sp.	CMPA
5LR11718	Black Shale Arroyo	16	2	127	123	125	11	BETA-287895	1060	40		Pinus sp.	CMPA
5LR11836			Unk	Unk	Unk	Unk	Unk	BETA-247836	4400	40	Burned parenchymous tissue	Atriplex sp., Acer negundo, pinus	CMPA
5LR12641	Harvester	2	1	38	20	29	12	BETA-284074	1000	40			Anderson 2012
5WL32	Uhl	2	3	39	36	37.5	8	GXO-319	1755	95			Wood 1967
5WL32	Uhl	4	1	43	37	40	8	GXO321	1972	160			Wood 1967
5WL32	Uhl	9	2	50	44	47	16	GXO-320	1955	95			Wood 1967
5WL48	Kersey Burial	10	1	55	60	57.5	15	BETA-48811	2810	80			Jepson et al. 1994
5WL48	Kersey Burial	12	1	55	60	57.5	15	BETA-48810	3230	80			Jepson et al. 1994
5WL48	Kersey Burial	15	1	55	60	57.5	15	BETA-48812	2830	50			Jepson et al. 1994
5WL48	Kersey Burial	17	1	55	60	57.5	15	BETA-48813	2290	50			Jepson et al. 1994
5WL101	Happy Hollow Rockshelter	5	1	61	61	61	15	GAK-1303	1270	80			Steege unsp.

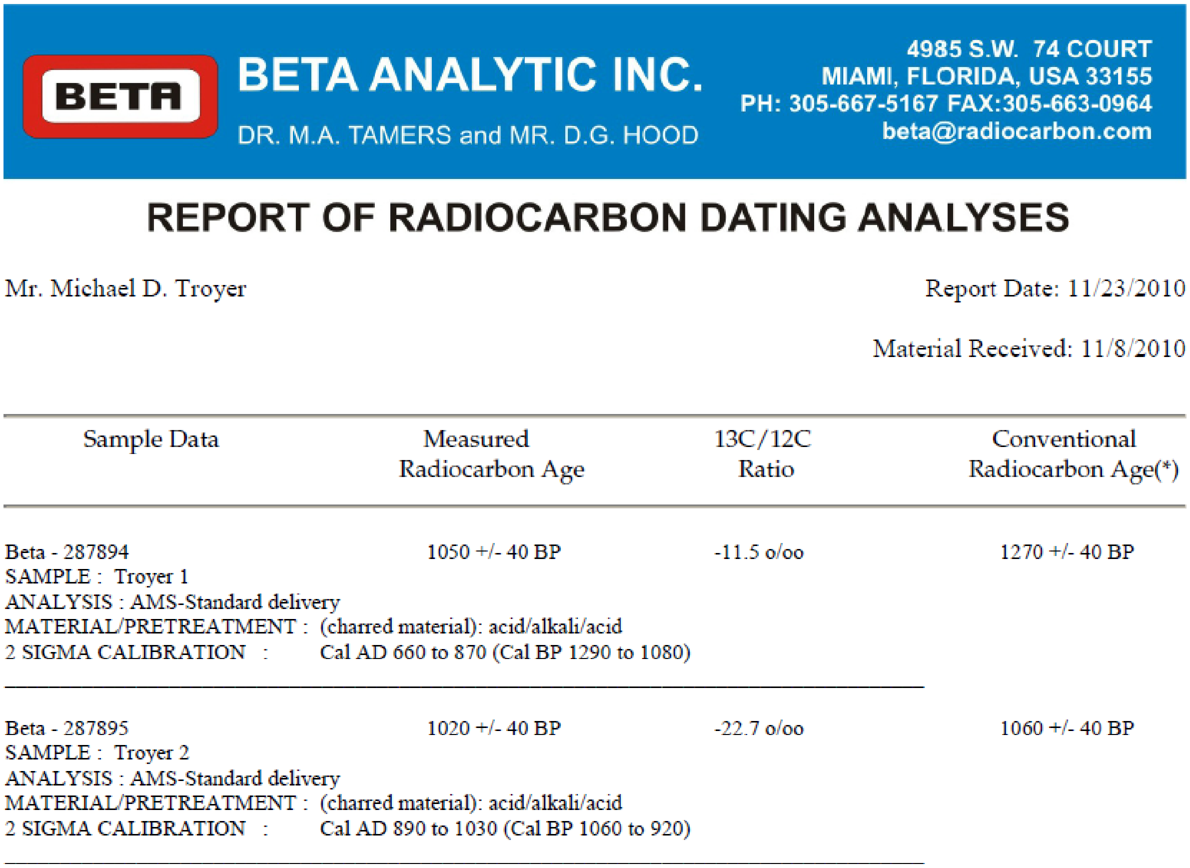
Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5WL101	Happy Hollow Rockshelter	6	3	35	35	35	Unk	GAK-1302	2170	80			Steege unsp.
5WL101	Happy Hollow Rockshelter	7	3	60	25	42.5	Unk	GAK-844	2680	90			Steege unsp.
5WL1483	Cass	1	1	50	48	49	14	BETA-47101	1240	80	Chenopodium sp.		Kalasz et al. 1993
5WL1483	Cass	2	1	54	50	52	8	BETA-33946	1460	50	Chenopodium sp. and Helianthus annus		Kalasz et al. 1993
5WL1483	Cass	4	2	Unk	Unk	Unk	Unk	BETA-47102	1370	60	Chenopodium sp.		Kalasz et al. 1993
5WL1483	Cass	6	1	55	50	52.5	5	BETA-47103	1184	70	Chenopodium sp.		Kalasz et al. 1993
5WL1555		5	1	50	50	50	20	BETA-48814	2070	100			Jepson et al. 1994
5WL1555		9	1	50	50	50	20	BETA-48815	2890	80	Chenopodium sp.		Jepson et al. 1994
5WL1656	Willow Bunker	1	2	100	100	100	10	ETH-20329	6775	75			Feiler 2001
5WL1656	Willow Bunker	2	2	100	100	100	10	ETH-20446	4530	70			Feiler 2001
5WL1656	Willow Bunker	20	1	60	60	60	10	ETH-23919	7570	65			Feiler 2001
5WL1656	Willow Bunker	20	2	70	70	70	10	ETH-23920	7125	65			Feiler 2001
5WL1794		8	1	55	55	55	12	BETA-59656	2970	90	Salsola sp.	Coniferae sp.	Painter et al. 1995
5WL1856	Rattlesnake Shelter	3	2	40	40	40	12	BETA-66569	1920	80			Brunswig 2001

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
5WL2382		7	2	50	50	50	20	Unk	1830	40	Chenopodium sp., Acanthoxanthium sp., and Glycyrrhiza sp.		Feiler 2001
5WL2383		16	1	75	75	75	40	ETH-23918	1610	50	Unk Seed		Feiler 2001
5WL2383		17	1	60	60	60	30	ETH-23917	1655	55	Unk Seed		Feiler 2001
5WL4088		1	1	42	42	42	13.5	BETA-167383	1100	40	Festuca sp. and Poaceae gen.		Kalasz et al. 2003
5WL5588	Hereford Crow Creek	4	1	52	52	52	15	BETA-240613	6250	40			Mark et al. 2009
5WL5588	Hereford Crow Creek	5	1	60	60	60	Unk	BETA-265837	5650	40			Anderson 2010
5WL5588	Hereford Crow Creek	6	1	50	49	49.5	8	BETA-265838	6540	40			Anderson 2010
5WL5588	Hereford Crow Creek	7A	1	50	48	49	14	BETA-265839*	6480	40			Anderson 2010
5WL5588	Hereford Crow Creek	7B	1	52	48	50	14	BETA-265839	6480	40			Anderson 2010
5WL5589		1	1	45	Unk	45	9	BETA-240614	6160	50			Mark et al. 2009
5WL5596		1	2	70	56	63	15	BETA-240615	3340	40			Mark et al. 2009
5WL5597	Bitter Mule	1	2	62	Unk	62	23	BETA-240616	5120	40			Mark et al. 2009
S10-2	Shady Grove	1	1	60	60	60	12.5	BETA-288156	1250	40		Atriplex sp. or Sacrobatus sp.	CMPA

Site	Site Name	Feature #	Type	Max Length (cm)	Max Width (cm)	Dia. (cm)	Max Depth (cm)	14C notes	14C dates	14CSTD	Macro	Fuel	Source
S10-2	Shady Grove	8	2	Unk	Unk	Unk	Unk	BETA-290565	1210	40			CMPA
S10-2	Shady Grove	13	2	Unk	Unk	Unk	Unk	BETA-290566	1330	40			CMPA

*** Feature Types: 1-Unlined, 2-Fire-Cracked Rock, 3-Rock-lined ** Interpreted as functionally related to feature 7b**

Appendix B – Radiocarbon Data



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REPORT OF RADIOCARBON DATING ANALYSES

Mr. Michael D. Troyer

Report Date: 11/23/2010

Material Received: 11/8/2010

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 287894 SAMPLE : Troyer 1 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 660 to 870 (Cal BP 1290 to 1080)	1050 +/- 40 BP	-11.5 o/oo	1270 +/- 40 BP
Beta - 287895 SAMPLE : Troyer 2 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 890 to 1030 (Cal BP 1060 to 920)	1020 +/- 40 BP	-22.7 o/oo	1060 +/- 40 BP

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-11.5:lab. mult=1)

Laboratory number: **Beta-287894**

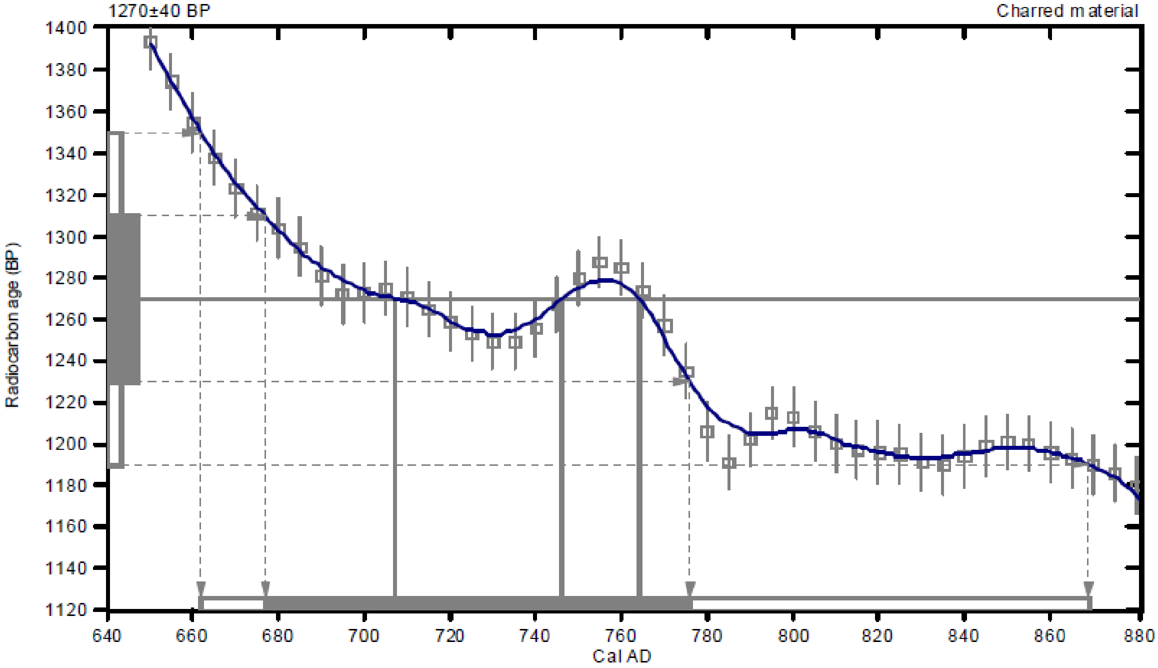
Conventional radiocarbon age: **1270±40 BP**

2 Sigma calibrated result: **Cal AD 660 to 870 (Cal BP 1290 to 1080)**
(95% probability)

Intercept data

Intercepts of radiocarbon age
with calibration curve:
Cal AD 710 (Cal BP 1240) and
Cal AD 750 (Cal BP 1200) and
Cal AD 760 (Cal BP 1190)

1 Sigma calibrated result: Cal AD 680 to 780 (Cal BP 1270 to 1170)
(68% probability)



References:
Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-22.7:lab. mult=1)

Laboratory number: **Beta-287895**

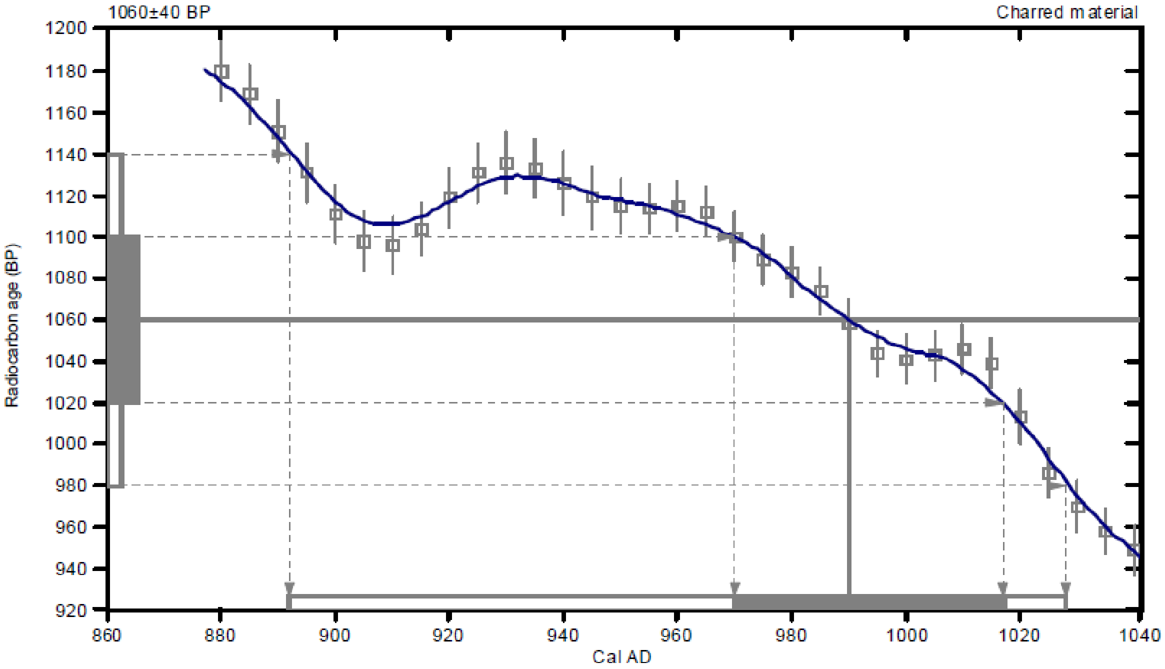
Conventional radiocarbon age: **1060±40 BP**

2 Sigma calibrated result: **Cal AD 890 to 1030 (Cal BP 1060 to 920)**
(95% probability)

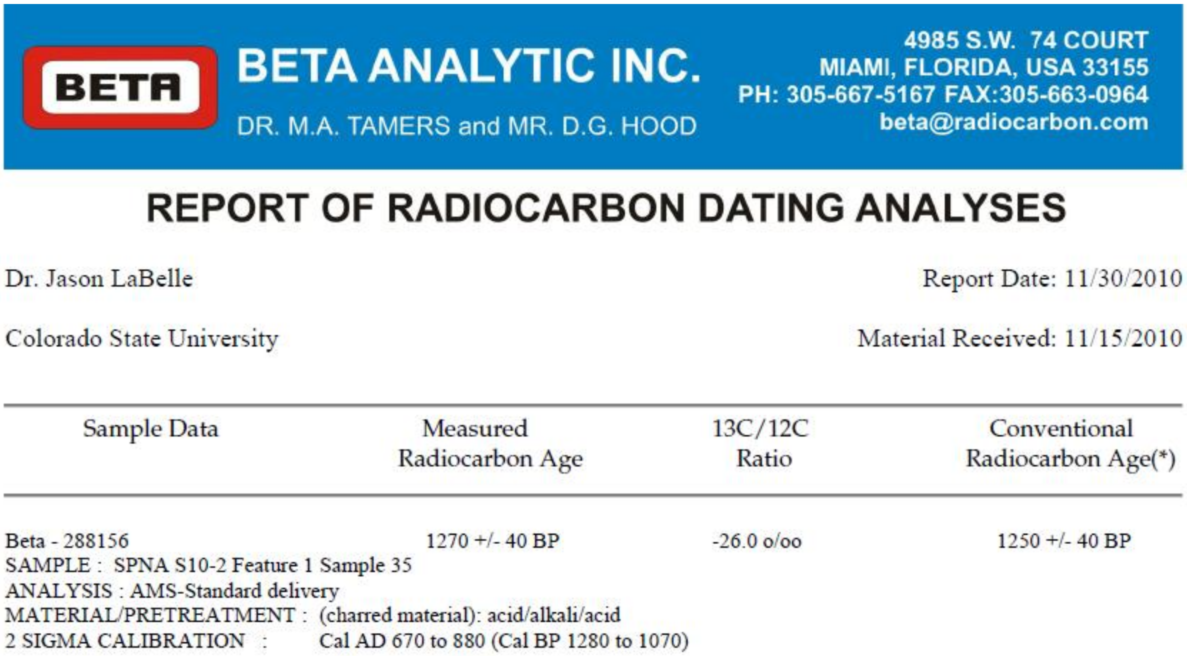
Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 990 (Cal BP 960)

1 Sigma calibrated result: Cal AD 970 to 1020 (Cal BP 980 to 930)
(68% probability)



References:
Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322



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REPORT OF RADIOCARBON DATING ANALYSES

Dr. Jason LaBelle — Report Date: 11/30/2010

Colorado State University — Material Received: 11/15/2010

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 288156	1270 +/- 40 BP	-26.0 o/oo	1250 +/- 40 BP

SAMPLE : SPNA S10-2 Feature 1 Sample 35
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 670 to 880 (Cal BP 1280 to 1070)

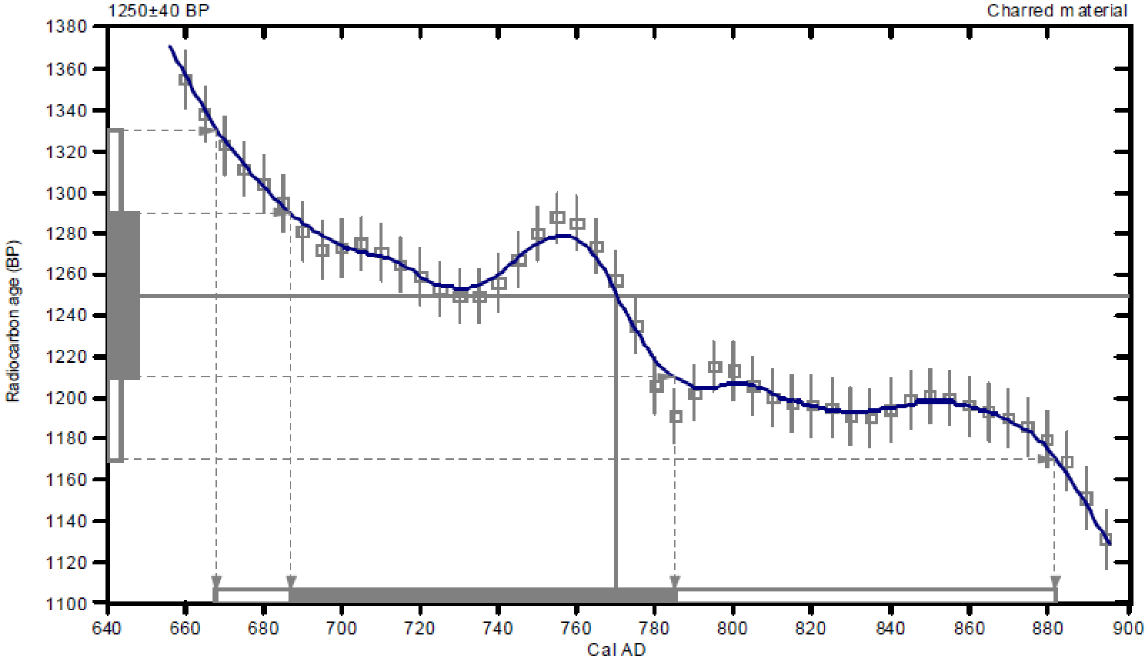
CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26:lab. mult=1)

Laboratory number:	**Beta-288156**
Conventional radiocarbon age:	**1250±40 BP**
2 Sigma calibrated result: **(95% probability)**	**Cal AD 670 to 880 (Cal BP 1280 to 1070)**

Intercept data

Intercept of radiocarbon age with calibration curve:	Cal AD 770 (Cal BP 1180)
1 Sigma calibrated result: (68% probability)	Cal AD 690 to 780 (Cal BP 1260 to 1160)



References:

Database used

INTCAL04

Calibration Database

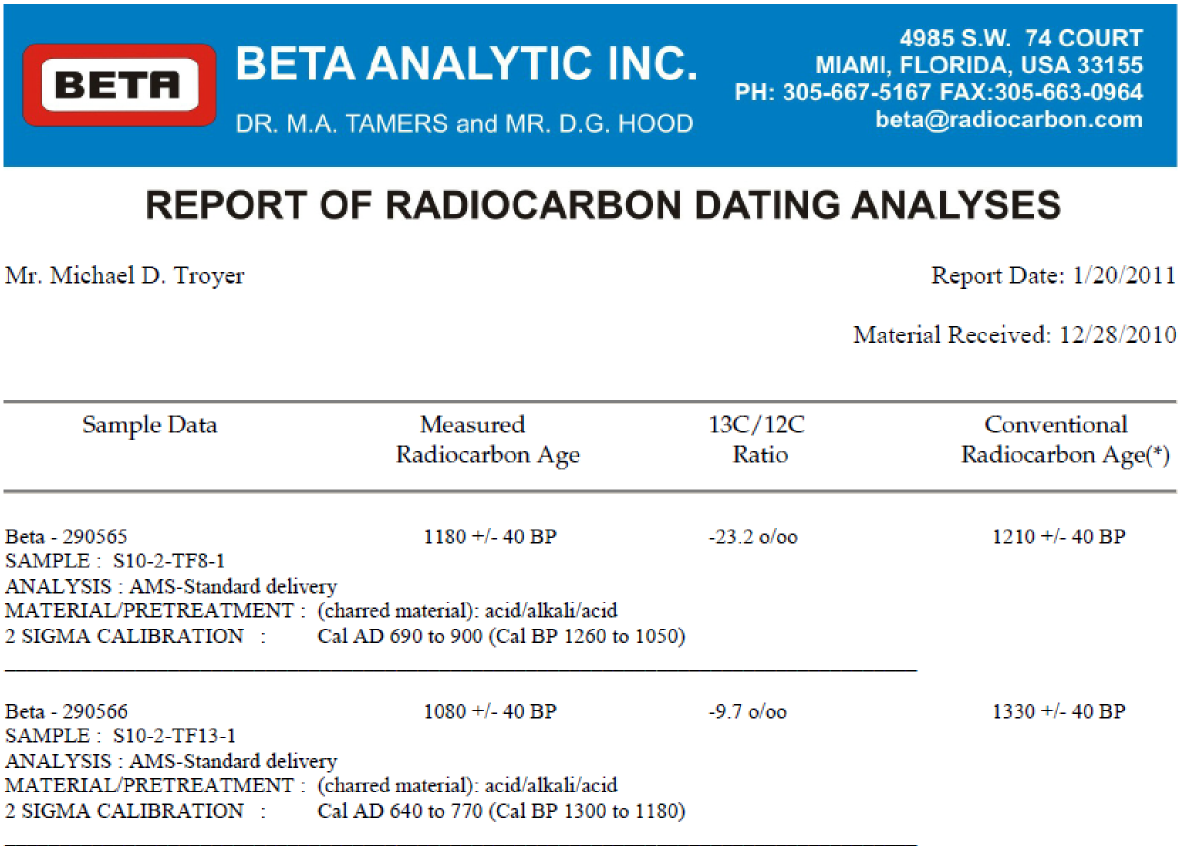
INTCAL04 Radiocarbon Age Calibration

IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).

Mathematics

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322



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REPORT OF RADIOCARBON DATING ANALYSES

Mr. Michael D. Troyer

Report Date: 1/20/2011

Material Received: 12/28/2010

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 290565 SAMPLE : S10-2-TF8-1 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 690 to 900 (Cal BP 1260 to 1050)	1180 +/- 40 BP	-23.2 o/oo	1210 +/- 40 BP
Beta - 290566 SAMPLE : S10-2-TF13-1 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 640 to 770 (Cal BP 1300 to 1180)	1080 +/- 40 BP	-9.7 o/oo	1330 +/- 40 BP

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.2:lab. mult=1)

Laboratory number: **Beta-290565**

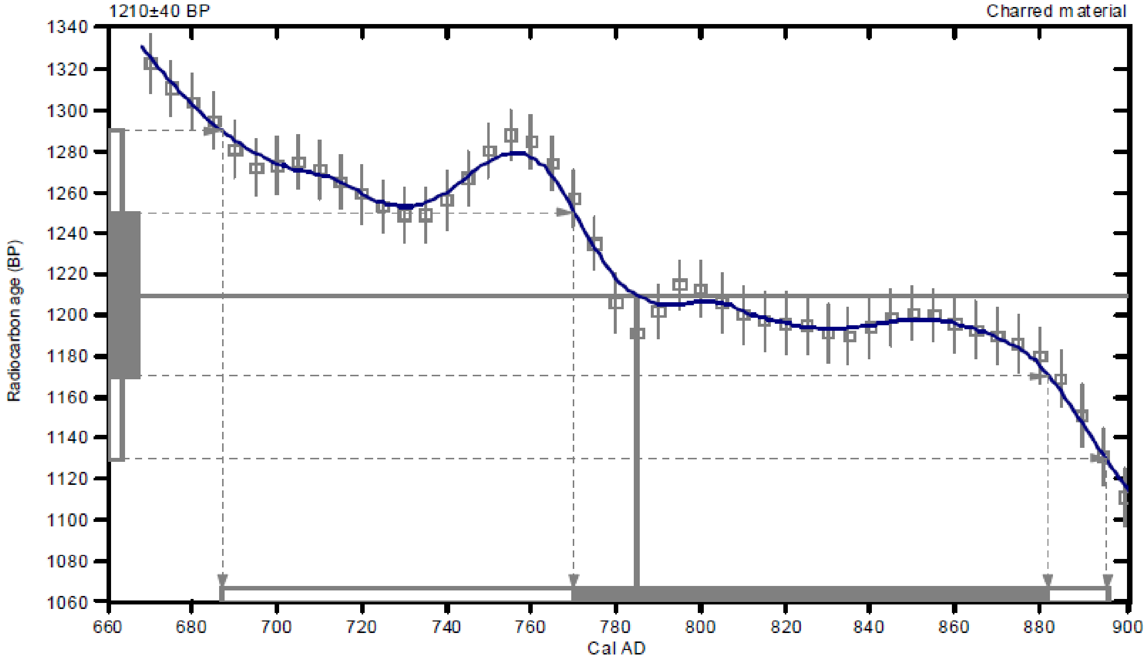
Conventional radiocarbon age: **1210±40 BP**

2 Sigma calibrated result: **Cal AD 690 to 900 (Cal BP 1260 to 1050)**
(95% probability)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 780 (Cal BP 1160)

1 Sigma calibrated result: Cal AD 770 to 880 (Cal BP 1180 to 1070)
(68% probability)



References:

Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-9.7:lab. mult=1)

Laboratory number: **Beta-290566**

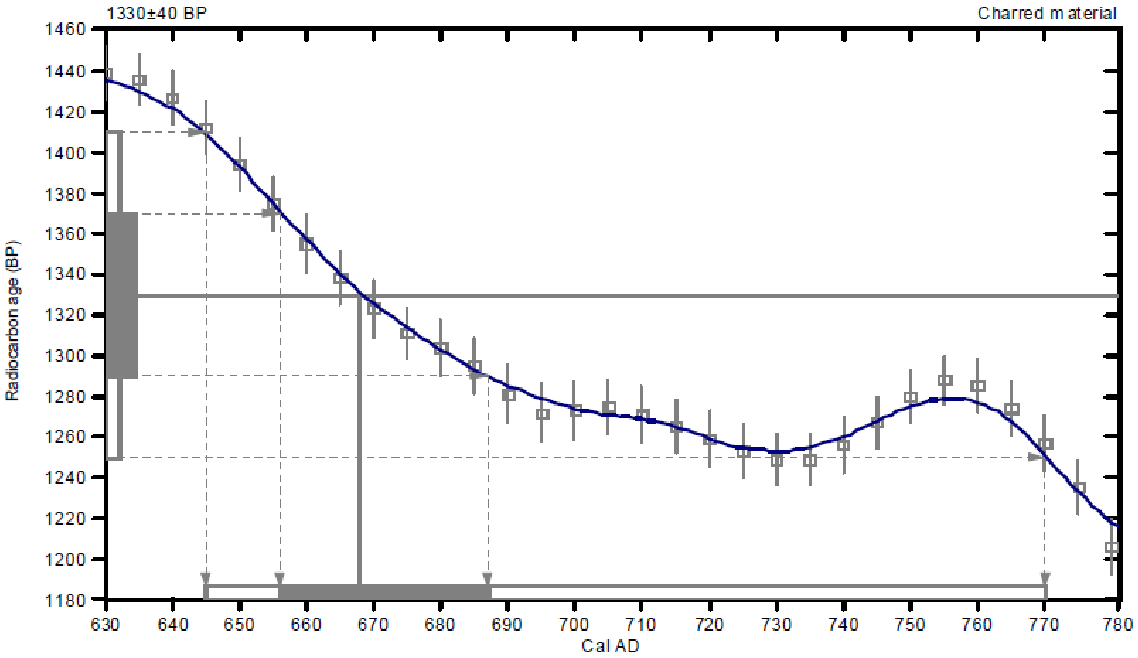
Conventional radiocarbon age: **1330±40 BP**

2 Sigma calibrated result: **Cal AD 640 to 770 (Cal BP 1300 to 1180)**
(95% probability)

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 670 (Cal BP 1280)

1 Sigma calibrated result: Cal AD 660 to 690 (Cal BP 1290 to 1260)
(68% probability)



References:
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INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

Appendix C – Macrobotanical Reports

MACROFLORAL ANALYSIS OF FEATURES 6 AND 16 AT 5LR11718

Prepared for:
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January 14, 2011

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Introduction:

Macrofloral analysis was conducted on Features 6 and 16 from Site 5LR11718. This was done to ascertain if charred macrofloral and non-macrofloral remains were present. If present, then insights into understanding prehistoric subsistence and subsistence patterns can lead to a better understanding of seasonality of site occupation, the possibility to reconstruct past plant and animal compositions, resource utilization patterns and the possibility to determine to what extent charred organic material has degraded. The overall results yielded three species of fuel wood, which were identified as pine (*Pinus* sp.), rabbitbrush (*Chrysothamnus* sp.), and a very small amount of probable greasewood (*Sarcobatus vermiculatus*). No carbonized or charred macrofloral remains were present in either of the samples. Unburned macrofloral remains were present and will be discussed later. In addition, insect chitin fragments were present and a representative sample was collected from each feature.

Methodology:

The light fraction was sent to High Plains Macrobotanical Services for analysis. The light fraction was passed through a 3", 2.0 mm, 1.0 mm and 0.5 mm sieves. Separating the light fraction into different sizes allows for more manageable viewing thereby decreasing the amount of time required to analyze a sample. Recovered macrofloral materials were identified using the author's seed and charcoal collections and seed and charcoal identification manuals (i.e., Core et al. 1979, Davis 1993, Hoadley 1990, Hurd et al. 1998, Kirkbrite et al. 2000, Martin and Barkley 2000, Musil 1978, Panshin and Zeeuw 1970, Young and Young 1992). Plant names are listed by both their common name and scientific name. The term 'sp' (such as *Pinus* sp.) indicates the plant has been identified to the genus level but not to the species level. The term 'seed' represents seeds, caryopses, and/or achenes.

Results:

Feature 6, Level 3, NW Quad 23 -28cm

Feature 6 was radiocarbon dated to 1270 ± 40 RCYBP. The entire light fraction sample was composed of charcoal while other materials such as roots or rootlets were absent. Two hundred and thirty-five grams of light fraction were examined and yielded one unburned plant thorn from an unknown plant species and one unburned and unknown plant leaf. Analysis of the charcoal yielded rabbitbrush (*Chrysothamnus* sp.). It should be noted some of the charcoal displayed “green burning.” Also of importance was the presence of some very large pieces of charcoal (see discussion).

One unburned insect chitin fragment was present in the light fraction and it was collected.

Feature 16, Level 2, NW Quad

Feature 16 was radiocarbon dated to 1060 ± 40 RCYBP. The light fraction sample was composed mainly of unburned grass and forb roots along with some charcoal. Two hundred and eight grams of light fraction were examined and yielded one unburned bastard toad flax (*Comandra umbellata*) seed fragment, one unburned and unknown plant leaf fragment and one unknown mustard silicle (similar to the introduced pennycress, *Thlaspi arvense*). Approximately 95% of the charcoal was pine (*Pinus* sp.) along with a few pieces of vitrified pinesap. Also present was approximately five percent probable greasewood (*Sarcobatus vermiculatas*) charcoal.

Numerous unburned insect chitin fragments were present in the light fraction and a representative sample was collected.

Discussion:

Unfortunately neither sample yielded any carbonized or charred macrofloral remains. One must remember these features could have been used for purposes other than plant processing. A review of the ethnographic record shows hearths used for food processing represents only one out of many possible uses. Some hearths were used as a source of light, food preparation (faunal and floral), fires in religious context, hunting-food gathering methods, tanning hides, signaling, fire as a tool in warfare, production of tools, keeping pests away, and play fires (Guernsey 1984: Appendix F). Additional uses include ceramic production, a place to gather and socialize (Bach 1998:5-6) and a hearth used to heat stones for regulating and storing heat (Ives 1999:17.1-2).

Feature 6 did not yield any carbonized or charred macrofloral remains. Due to that, it is unknown what purpose or function it may have served. Feature 6 contained rabbitbrush charcoal which showed evidence of green burning. That is to say, the plant was collected while it was still alive. Evidence for this can be found in the tangential and radial cracks present in the early wood to latewood (for more information about this, see Boonstra et al. 2006a and 2006b). Generally speaking, when moisture is present, such as in a living branch, and this branch is introduced into a fire, that moisture turns into steam, which in turn, expands destroying the cell wall structures while the steam is trying to escape. If you have ever sat around the campfire and you hear the wood popping, that is the moisture escaping from the wood. This type of phenomenon generally does not occur in dead wood due to the absent of moisture.

Feature 6 also contained very large pieces of charcoal. These pieces suggest that a very large plant(s) was collected and burned. Normally, the diameter of rabbitbrush does not become much larger than a person’s thumb (Bach: Personal Observation) unless that plant has tapped into a source of moisture i.e., rabbitbrush growing next to a draw or creek or if it has tapped into an underground spring etc. The charcoal recovered from Feature 6 suggests that the plant(s) was collected next to a water source.

Feature 16 did not yield any carbonized or charred macrofloral remains. Due to that, it is unknown what purpose or function it may have served. Approximately 95% of the charcoal was pine while the remaining five percent was probably greasewood. Other species such as saltbush (*Atriplex* sp.) display very similar morphological characteristics, which make identifying the charcoal difficult.

It is no surprise pine was being selected over greasewood. Pine is easier to collect and has significantly longer burn duration. On the other hand, the presence of the greasewood, in such small quantities, may represent greasewood being used as kindling.

The presence of the unburned seeds and other plant material should be considered intrusive and dismissed. Keepax (1977:226) stated “It is often a simple matter to reject all uncharred seeds (and other unburned material) as modern in origin and to retain only the charred material as genuine.” The presence of the insect chitin fragments indicates these features have undergone very limited modern day bioturbation/disturbance. This bioturbation/disturbance does not appear to have affected the overall preservation of the feature contents.

References Cited:

Bach, Daniel R.
1998 Macrofloral Analysis of Three Features From 48AB806. Report prepared for The Office of the Wyoming State Archaeologist. M.S. on file, High Plains Macrobotanical Services. Laramie, Wyoming.

Boonstra, M. J., J. F. Rijsdijk, C. WSander, E. Kegel, B. Tjeerdsma, H. Militz, J. Van Acker, M. Stevens.
2006a Microstructural and Physical Aspects of Heat Treated Wood. Part 1. Softwoods. *Maderas. Ciencia y tecnología* 8 (3): 193-208.

Boonstra, M. J., J. F. Rijsdijk, C. WSander, E. Kegel, B. Tjeerdsma, H. Militz, J. Van Acker, M. Stevens.
2006b Microstructural and Physical Aspects of Heat Treated Wood. Part 2. Hardwoods. *Maderas. Ciencia y tecnología* 8 (3): 209-218.

Core, H.A., W.A. Cote and A.C. Day
1979 *Wood Structure and Identification. 2nd Ed.* Syracuse University Press. Syracuse, New York.

Davis, Linda W.
1993 *Weed Seeds of the Great Plains: A Handbook for Identification*. University Press of Kansas. Lawrence, Kansas.

Guernsey, Karin M.
1984 Appendix F: Ethnographic Review of Various Functions of Firehearths. In *Final Report of Investigations along the Cities Service 12, 8, and 6 Inch Pipeline, Sweetwater County, Wyoming*. William R. Latady, Jr. Ed. Office of the Wyoming State Archaeologist, Laramie. MS on file, Wyoming Cultural Records Office, Laramie, Wyoming.

Hoadley, R. Bruce
1990 *Identifying Wood: Accurate Results with Simple Tools*. Taunton Press, Newtown, Connecticut.

Hurd, Emerenciana G., Nancy L. Shaw, Jay Mastrogiuseppe, Lynda C. Smithman, and Sherel Goodrich.
1998 *Field Guide to Intermountain Sedges*. United States Department of Agriculture, Forest Service. General Technical Report RMRS-GTR

Ives, Ryan
1999 Chapter 17: Fire-Modified Rocks From Site 45CA426 Component 2. In, The SR-101 Sequim Bypass Archaeological Project: Mid- to Late-Holocene Occupations on the Northern Olympic Peninsula, Clallam County, Washington. Edited by Vera E. Morgan. Submitted to Washington Department of Transportation TAD GP and TAD HJ. *Eastern Washington University Reports in Archaeology and History 100-108*. Archaeological and Historical Services, Cheney.

Keepax, Carole
1977 Contamination of archaeological deposits by seeds of modern origin with particular reference to the use of flotation. *Journal of Archaeological Sciences* 4: 221-229.

Kirkbride, J., Gunn, Charles R., Anna L. Weitzman, and Michael J. Dallwitz
2000 *Legume (Fabaceae) Fruits and Seeds*. Parkway Publisher, Inc. Boone, North Carolina.

Martin, Alexander C., and William D. Barkley
2000 *Seed Identification Manual*. The Blackburn Press. Caldwell, New Jersey.

Musil, Albina F.
1978 *Identification of Crop and Weed Seeds, Agricultural Handbook No. 219*. U.S. Government Printing Office. Washington, D.C.

Panshin, A. J., and Carl de Zeeuw
1970 *Textbook of Wood Technology: Vol. 1: structure, identification, uses, and properties of the commercial woods of the United States and Canada, 3rd Ed.* McGraw-Hill, New York.

Young, James A., and Cheryl G. Young
1992 *Seeds of Woody Plants in North America*. Dioscorides Press. Portland, Oregon.

MACROFLORAL ANALYSIS OF SIX FEATURES AND CHARCOAL IDENTIFICATION OF 11 SAMPLES FROM LARIMER COUNTY, COLORADO.

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Introduction:

Macrofloral analysis was conducted on six features and 11 charcoal identification samples from Larimer County, Colorado. This was done to ascertain if charred macrofloral and non-macrofloral remains were present. If present, then insights into understanding prehistoric subsistence and subsistence patterns can lead to a better understanding of seasonality of site occupation, the possibility to reconstruct past plant and animal compositions, resource utilization patterns and the possibility to determine to what extent charred organic material has degraded. The overall results yielded primarily ponderosa pine (*Pinus ponderosa*) charcoal, however, cottonwood/aspen (*Populus* sp. / *Salix* sp.), birch (*Betula* sp.), juniper (*Juniperus* sp.), ash (*Fraxinus* sp.), saltbush or greasewood (*Atriplex* sp. *Sarcobatus* sp.), and one unknown species were also present. Carbonized macrofloral remains were absent in the light fraction. Unburned macrofloral remains were present and will be discussed below. Sample 5LA110, EATF2-MB1 contained six burned bone fragments from a Size Cass 2 individual. These burned bone fragments suggest cooking of a small animal was one of the purposes of that feature. Other zoological remains included unburned *Vallonia* sp. and *Pupillia* sp. gastropods in addition to one unknown genus of gastropods.

Methodology:

The samples were floated using an Archaeon style water flotation device. This machine consists of a small, metal reservoir, which is connected to a water hose. The samples are poured into the water filled reservoir while incoming water from a dispersal nozzle agitates and swirl the sediment causing the organic fraction to float off into a fine meshed geological sieve (0.063 mm),(see Limp 1973). If the sample contained clay, boiling hot water was added to the bucket and it was allowed to sit for ten minutes at which time a small amount of agitation was added. This technique literally liquefied the clay. Cold water was then added to the bucket and the sample was floated. The heavy fraction was water screened through a 1.0 mm sieve. Size grade of the heavy fraction is based on the Unified Soil Classification system. The material was air dried and examined for cultural (i.e., bone fragments, trade beads etc.) and non-cultural (gastropods) remains. The light fraction was passed through a 6.35mm (1/4”) screen sieve, a 2.0mm, 1.0mm, and 0.5 mm sieves. Separating the light fraction into different sizes allows for more manageable viewing thereby decreasing the amount of time required to analyze a feature. Recovered macrofloral materials were identified using the author’s seed and charcoal collection and wood and seed identification manuals (i.e., Boonstra et al. 2006a, Boonstra et al. 2006b, Core et al. 1979, Davis 1993, Hoadley 1990, Hurd et.al. 1998, Kirkbride et al. 2000, Martin and Barkley 2000, Musil 1978, Panshin and Zeeuw 1970, Young and Young 1992).

Charcoal fragments were removed from the 6.35mm, the 2mm, and 1mm screens. The charcoal was weighed and recorded. Plant names are listed by both their common name and scientific name. Scientific nomenclature of plant names changes over time (see Dorn 2001; Scianna and Majerus 2002). Due to this, the new scientific name will be used throughout this report if appropriate. The term 'sp.' (such as *Pinus* sp.) indicates the plant has been identified to the genus level but not to the species level. The term 'seed' represents seeds, caryopses, and/or achenes.

Grain size of the quartzite and sandstone found in the heavy fraction are based on the Unified Soil Classification System (USCS).

Results:

5LR110, CF1-MB1

Approximately 250 ml of feature fill was floated yielding 5.90 grams of organic material, which was composed primarily of charcoal. A total of 3.69 grams of ponderosa pine (*Pinus ponderosa*) charcoal was present in the light fraction, of which, 1.20 grams of charcoal were recovered in the 6.35mm screen, 1.44 grams in the 2mm screen and approximately 10.05 grams in the 1mm screen. Unburned macrofloral remains included three lupine (*Lupinus* sp.) seeds, one fragmented prickly pear cactus (*Opuntia polyacantha*) seed, and one mustard silicle. Zoological remains included one Size Class 2 or larger unburned bone fragment (all spongy bone) and one Size Class 1 bone fragment displaying a Burning Stage of 1 and a Weathering Pattern of 0. Also present was one rodent size piece of scat. One complete *Pupillia* sp. and one fragmented *Vallonia* sp. gastropod were also present.

The heavy fraction yielded 34.26 grams, which was composed of sub-rounded sandstone ranging in size from 0.43mm – 2.0mm (medium grain size) to 19mm-75mm (coarse grain size).

Some of the sandstone displays minor heat altering. The heavy fraction yielded one chert pressure flake.

5LA110, EATF2-MB1

Less than a liter of fill was floated yielding 1.80 grams of organic material, which was composed primarily of charcoal. A total of 1.20 grams of ponderosa pine (*Pinus ponderosa*) charcoal was present in the light fraction, of which, 0.90 grams of charcoal were recovered in the 2mm screen and 0.30 grams in the 1mm screen. No carbonized, charred, or unburned macrofloral remains were present in the light fraction. Zoological remains included one unburned Size Class 2 bone fragment displaying a Weathering Pattern of 1 and six Size Cass 2 bone fragments displaying a Burning Stage of 1 and 2 with a Weathering Pattern of 1. Also present was one unburned *Vallonia* sp. gastropod.

The heavy fraction yielded 32.23 grams, which was composed of quartzite and sandstone ranging in size from 0.43mm – 2.0mm (medium grain size) to 19mm-75mm (coarse grain size). The quartzite grains were generally sub-angular to sub-round. The majority of the sandstone displays some heat altering and there are several pieces of quartzite fire cracked rock (FCR) ranging in size up to 40mm. The heavy fraction yielded four chert pressure flakes.

5LR110, CF2-MB1

Approximately 250 ml sample of feature fill was floated yielding 0.49 grams of organic material, which was composed primarily of charcoal. A total of 0.15 grams of ponderosa pine (*Pinus ponderosa*) charcoal was present in the light, of which, 0.04 grams were recovered in the 2mm screen and 0.11 grams in the 1mm screen. Carbonized, charred or unburned macrofloral remains were absent in the light fraction. Zoological remains included four unknown gastropod species.

The heavy fraction yielded 270.05 grams, which was composed of sandstone ranging in size from 0.43mm – 2.0mm (medium grain size) to 19mm-75mm (coarse grain size). None of the sandstone appears to be heat altered. Cultural materials were absent.

<u>5LR11569, TF1-MB1, CM2</u>

A one-liter sample of feature fill was floated yielding 40.32 grams of organic material, which was composed primarily of charcoal. A total of 32.46 grams of charcoal was present in the light fraction, of which, 11.31 grams were recovered in the 6.35mm screen, 13.49 grams in the 2mm screen and 7.66 grams in the 1mm screen. Ponderosa pine (*Pinus ponderosa*) charcoal was the primary species present however, birch (*Betula* sp.), cottonwood/aspen (*Populus* sp. /*Salix* sp.), ash (*Fraxinus* sp.), juniper (*Juniperus* sp.), and an unknown species were also present. Carbonized or charred macrofloral remains were absent in the light fraction. Unburned macrofloral remains included one brome (*Bromus* sp.) floret. Zoological remains were absent in the light fraction.

The heavy fraction yielded 6.15 grams which was composed primarily of sandstone but also had a small amount of quartzite ranging in size from 0.43mm – 2.0mm (medium grain size) to 19mm-75mm (coarse grain size). The quartzite is sub-angular to sub-round. None of the heavy fraction appears to be heat altered. Cultural materials were absent.

<u>LR11585, TF3-MB1, CM3</u>

A 1.25-liter sample of feature fill was floated yielding 82.02 grams of organic material, which was composed primarily of charcoal. A total of 71.23 grams of predominately ponderosa pine (*Pinus ponderosa*) charcoal was present in the light fraction. Juniper (*Juniperus* sp.) charcoal may also be present but given the small pieces of the charcoal analyzed, one cannot definitively state that the charcoal is juniper. With that said, 46.22 grams of charcoal were recovered in the 6.35mm screen, 17.06 grams in the 2mm screen and 7.95 grams in the 1mm screen. Carbonized, charred or unburned macrofloral remains were absent in the light fraction. Zoological remains included 11 unburned *Vallonia* sp. gastropods.

The heavy fraction yielded 84.08 grams which was composed primarily of sandstone with trace amounts of quartzite ranging in size from 0.43mm – 2.0mm (medium grain size) to 19mm-75mm (coarse grain size). The quartzite grains were generally sub-angular to sub-round. A minority of the sandstone displays some heat altering and there are several pieces of heat-altered sandstone ranging in size from 10mm up to 50mm. Cultural materials were absent.

5LR11711, 2nd arroyo hearth, CM4

A 1.75-liter sample of feature fill was floated yielding 60.45 grams of organic material, which was primarily of charcoal. A total of 32.54 grams of ponderosa pine (*Pinus ponderosa*) charcoal was present in the light, of which, 10.24 grams were recovered in the 6.35mm screen, 11.94 grams in the 2mm screen and 10.36 grams in the 1mm. Carbonized, charred or unburned macrofloral remains were absent in the light fraction. Zoological remains included eight unburned *Pupillia* sp., two *Vallonia* sp., and one unknown gastropod.

The heavy fraction yielded 20.71 grams which was composed primarily of sandstone with trace amounts of quartzite ranging in size from 0.43mm – 2.0mm (medium grain size) to 19mm-75mm (coarse grain size). The quartzite grains were generally sub-angular to sub-round. A few pieces of the sandstone display some heat altering. Cultural materials were absent.

Charcoal identification was conducted on 11 samples. The results are found in Table 1.

Table C-1: Summary of Charcoal Identification

SAMPLE #	IDENTIFICATION	COMMENTS
CMPA11-1	Ponderosa pine	
CMPA11-2	Ponderosa pine	
CMPA11-3	Ponderosa pine	
CMPA11-4	Cottonwood/aspen	
CMPA11-5	Saltbush or greasewood	
CMPA11-6	Ponderosa pine	
CMPA11-7	Ponderosa pine	
CMPA11-8	Juniper	
CMPA11-11	Birch?	Can't rule out other possibilities
CMPA11-12	Birch	
CMPA11-14	Ponderosa pine	

Discussion:

Unfortunately, none of the features analyzed contained any carbonized or charred macrofloral remains. Due to that, it is unknown what purpose or function those features may have served. One must remember these features could have been used for purposes other than plant processing. A review of the ethnographic record shows hearths used for food processing represents only one out of many possible uses. Some hearths were used as a source of light, food preparation (faunal and floral), fires in religious context, hunting-food gathering methods, tanning hides, signaling, fire as a tool in warfare, production of tools, keeping pests away, and, play fires (Guernsey 1984: Appendix F). Additional uses include ceramic production, a place to gather and socialize (Bach 1998:5-6), and, a hearth used to heat stones for regulating and storing heat (Ives 1999:17.1-2).

Sample 5LR110, CF1-MB1 and Sample 5LA110, EATF2-MB1 contained lithic materials. The presence of the chert pressure flakes could suggest a person sitting around a campfire making or re-sharpening a stone tool or a cleaning episode. Another explanation has been proposed by Leach and Bousman (2004). The presence of flakes in a hearth might be explained through the action of borrowing surrounding sediment to seal an earth oven "feature":

> The process of borrowing sediment has serious implications for site structure, and primary and secondary formation processes. It is assumed that foods cooked in earth ovens were covered and sealed with an earthen cap. While direct archaeological evidence is absent, this assumption is probably a reasonable one, as most ethnographic accounts of cooking in earth ovens describe the construction of an earthen cap, and indirect evidence has been obtained from the analysis of size sorting of artifacts down-slope of a midden at the Culebra Creek site in San Antonio, Texas (Leach and Bousman 2001). If sediment was used to cap earth ovens in burned rock midden deposits, then it is highly probable that the collection of sediment to build these caps resulted in the disturbance of the surrounding ground surface during the process of borrowing (Leach and Bousman 2004:2).

None of the chert flakes appeared to be heat treated. Are we looking at a roasting pit that was sealed with the surrounding sediment as proposed by Leach and Bousman (2004) or are we looking at a cleaning episode where the surrounding debris was discarded in the hearth? Based on the limited evidence at hand, this author suspects re-sharpening of a stone tool or a cleaning episode is a more likely scenario.

Sample 5LR110, CF1-MB1 contained one rodent (Size Class 1—see Brain 1981) burned bone displaying a Burning Stage of 1 (see Shipman and Schoeninger 1984: 313) and a Weathering Pattern of 0 (see Lyman and Fox 1989; Todd et al. 1987). The question remains, "is this burned bone culturally significant?" According to Whyte (1981), the rodent bone may not be but rather represents a small rodent becoming trapped in a feature and dying. This author has also observed modern deceased rodents in campfires along with blown in plant debris so it is feasible that these bone fragments are the result of a trapped individual, which at a later date, the feature was then reused. Conversely, we know Native Americans were opportunistic and did procure rodents (see Walker1986). Sample 5LA110, EATF2-MB1 contained six Size Cass 2 bone fragments displaying a Burning Stages of 1 and 2 with a Weathering Pattern of 1. These burned bone fragments are more definitive and suggest cooking of small animals was one of the purposes of that feature.

Several of the features contained unburned gastropods including *Vallonia* sp. and *Pupillia* sp. (see Rocque 1970) and one unknown species. These gastropods were identified only to the genus level. Due to that, it is unknown if these gastropods are a good climatic indicator or not. What is known is they are unburned and therefore represent post site occupation.

The presence of the ponderosa pine (*Pinus ponderosa*) charcoal, the cottonwood/aspen (*Populus* sp./ *Salix* sp.), the birch (*Betula* sp.) charcoal, the juniper (*Juniperus* sp.) charcoal, the ash (*Fraxinus* sp.) charcoal, the saltbush or greasewood (*Atriplex* sp.. *Sarcobatus* sp.) and the one unknown species of charcoal indicates a diverse ecosystem. This could represent either the foothills or mountain ecosystem along the Front Range (see Weber 1976, 1990).

Also, according to Tennessen et al., "Accurate taxonomic identification is an essential part of archaeological wood analysis. However, making identifications more precise than the genus level is usually not possible since species within the same genus (and sometimes family) typically possess very similar cellular morphology (Tennessen et al. 2002:521). Due to that, the cottonwood/aspen (*Populus* sp. / *Salix* sp.) and the saltbush or greasewood (*Atriplex* sp. *Sarcobatus* sp.) could not be identified beyond the family level.

The presence of the unburned seeds should be considered intrusive and dismissed. Keepax (1977:226) stated "It is often a simple matter to reject all uncharred seeds as modern in origin and to retain only the charred material as genuine."The presence of a few plants indicates these features have undergone limited modern day bioturbation/disturbance. This bioturbation/disturbance does not appear to have affected the overall preservation of the feature contents (see Bach 2005).

To summarize, macrofloral analysis was conducted on 6 features and 11 charcoal identification samples from Larimer County, Colorado. The overall results yielded primarily ponderosa pine (*Pinus ponderosa*) charcoal, however, cottonwood/aspen (*Populus* sp. / *Salix* sp.), birch (*Betula* sp.), juniper (*Juniperus* sp.), ash (*Fraxinus* sp.), saltbush or greasewood (*Atriplex* sp. *Sarcobatus* sp.), and one unknown species were also present. Carbonized macrofloral remains were absent in the light fraction. Sample 5LA110, EATF2-MB1 contained six Size Cass 2 bone fragments displaying a Burning Stages of 1 and 2 with a Weathering Pattern of 1. These burned bone fragments are more definitive and suggest cooking of small animals was one of the purposes of that feature. The remaining features did not contain any carbonized or charred macrofloral or faunal remains. Due to that, it is unknown what purpose these features may have served. Zoological remains included unburned *Vallonia* sp. and *Pupillia* sp. gastropods in addition to one unknown genus of gastropods.

References Cited:

Bach, Daniel R.

1998 Macrofloral Analysis of Three Features from 48AB806. Report prepared for The Office of the Wyoming State Archaeologist. M.S. on file, High Plains Macrobotanical Services. Laramie, Wyoming.

2005 Macrofloral and Limited Geomorphological Analysis of 750 Prehistoric Hearths from Southwestern Wyoming. Paper presented at the *7th Biennial Rocky Mountain Anthropological Conference*, Park City, Utah. September 15th - 18th, 2005.

Brain, C. K.

1981 *The Hunter or the Hunted? An Introduction to African Cave Taphonomy*. University of Chicago Press, Chicago.

Boonstra, M. J., J. F. Rijsdijk, C. WSander, E. Kegel, B. Tjeerdsma, H. Militz, J. Van Acker, M. Stevens.

2006a Microstructural and Physical Aspects of Heat Treated Wood. Part 1. Softwoods. *Maderas. Ciencia y tecnología* 8 (3): 193-208.

Boonstra, M. J., J. F. Rijsdijk, C. WSander, E. Kegel, B. Tjeerdsma, H. Militz, J. Van Acker, M. Stevens.

2006b Microstructural and Physical Aspects of Heat Treated Wood. Part 2. Hardwoods. *Maderas. Ciencia y tecnología* 8 (3): 209-218.

Core, H.A., W.A. Cote and A.C. Day

1979 *Wood Structure and Identification. 2nd Ed.* Syracuse University Press. Syracuse, New York.

Davis, Linda W.

1993 *Weed Seeds of the Great Plains: A Handbook for Identification*. University Press of Kansas. Lawrence, Kansas.

Dorn, Robert D.

2001 *Vascular Plant of Wyoming, 3rd Ed.* Mountain West Publishing. Cheyenne, WY.

Guernsey, Karin M.

1984 Appendix F: Ethnographic Review of Various Functions of Firehearths. In *Final Report of Investigations along the Cities Service 12, 8, and 6 Inch Pipeline, Sweetwater County, Wyoming*. William R. Latady, Jr. Ed. Office of the Wyoming State Archaeologist, Laramie. MS on file, Wyoming Cultural Records Office, Laramie, Wyoming.

Hoadley, R. Bruce

1990 *Identifying Wood: Accurate Results with Simple Tools*. Taunton Press, Newtown, Connecticut.

Hurd, Emerenciana G., Nancy L. Shaw, Jay Mastrogiuseppe, Lynda C. Smithman, and Sherel Goodrich.

1998 *Field Guide to Intermountain Sedges*. United States Department of Agriculture, Forest Service. General Technical Report RMRS-GTR

Ives, Ryan

1999 Chapter 17: Fire-Modified Rocks From Site 45CA426 Component 2. In, The SR-101 Sequim Bypass Archaeological Project: Mid- to Late-Holocene Occupations on the Northern Olympic Peninsula, Clallam County, Washington. Edited by Vera E. Morgan. Submitted to Washington Department of Transportation TAD GP and TAD HJ. *Eastern Washington University Reports in Archaeology and History 100-108*. Archaeological and Historical Services, Cheney.

Keepax, Carole

1978 Contamination of archaeological deposits by seeds of modern origin with particular reference to the use of flotation. *Journal of Archaeological Sciences* 4: 221-229.

Kirkbride, J., Gunn, Charles R., Anna L. Weitzman, and Michael J. Dallwitz

2000 *Legume (Fabaceae) Fruits and Seeds*. Parkway Publisher, Inc. Boone, North Carolina.

Leach, Jeff D. and C. Britt Bousman

2004 Comments on Assigning a Primary Context to Artifacts Recovered from Burned Rock Middens. Article submitted (Dec. 2003) to *Journal of Field Archaeology*. http://www.cookstonetechnology.com/site_formation_midden.htm

Limp, W. F.

1970 Water Separation and Flotation Processes. *Journal of Field Archaeology* 1:337-342.

Lyman, R. L., and G. L. Fox

1989 A Critical Evaluation of Bone Weathering as an Indication of Bone Assemblage Formation. *Journal of Archaeological Science* 16: 293-317.

Martin, Alexander C., and William D. Barkley

2000 *Seed Identification Manual*. The Blackburn Press. Caldwell, New Jersey.

McWeeney, Lucinda

1989 What lies lurking below the soil: beyond the archaeobotanical view of floatation samples. In *North American Archaeologist*, Vol. 10 (3) 227-230. Baywood Publishing Co., Inc.

Musil, Albina F.

1978 *Identification of Crop and Weed Seeds, Agricultural Handbook No. 219*. U.S. Government Printing Office. Washington, D.C.

Panshin, A. J., and Carl de Zeeuw

1970 Textbook *of Wood Technology: Vol. 1: structure, identification, uses, and properties of the commercial woods of the United States and Canada, 3rd Ed.* McGraw-Hill, New York.

Rocque, Aurele La

1970 *Pleistocene Mollusca of Ohio Part 4, Bulletin 62.* State of Ohio, Department of Natural Resources. Division of Geological Survey. Columbus, Ohio

Scianna, Joseph D. And Mark E. Majerus

2002 Plant Materials Tech Note: Current Nomenclature of Plant Species Used in Conservation Activities in Montana and Wyoming. *United States Department of Agriculture*, Natural Resources Conservation Service. Plant Materials Technical Note No. MT-41.

Shipman, P., Giraud Foster, and Margaret Schoeninger

1984 Burnt Bones and Teeth: An Experimental Study of Color, Morphology, Crystal Structure, and Shrinkage. *Journal of Archaeological Science* 11: 307-325.

Tennessen, David, Robert A. Blanchette, Thomas C. Windes

2002 Differentiating Aspen and Cottonwood in Prehistoric Wood from Chacoan Great House Ruins. *Journal of Archaeological Science* 29: 521-527.

Todd, L. C., R. V. Witter, and G. C. Frison

1987 Excavation and Documentation of the Princeton and Smithsonian Horner Site Assemblages. In (G. C. Frison and L.C. Todd, eds.) *The Horner Site: The Type Site of the Cody Cultural Complex*, pp. 39-91. Orlando: Academic Press.

Weber, William

1976 *Rocky Mountain Flora*. Colorado Associated University Press, Boulder, Colorado

1992 *Colorado Flora: Eastern Slope*. University Press of Colorado, Niwot, Colorado

Walker, Danny N.

1987 Archaeological evidence for the use of small mammals by prehistoric inhabitants on the Northwestern High Plains. In: The Prairie: Roots of our culture; foundation of our economy, edited by Arnold Davis and Geoffrey Stanford. *Proceedings of the Tenth North American Prairie Conference*. Dallas, Texas, Native Prairie Association of Texas, pp. 6.08.1-6.08.6.

Whyte, Tomas R.

1970 Small-Animal Remains in Archaeological Pit Features. In Beamers, Bobwhites, and Blue-Points: Tributes to the Career of Paul W. Parmalee. James R. Purdue, Walter E. Klippel, and Bonnie W. Styles (editors*). Illinois State Museum Scientific Papers, Vol.23*, Springfield, Illinois

Young, James A., and Cheryl G. Young
1992 *Seeds of Woody Plants in North America*. Dioscorides Press. Portland, Oregon.

Appendix D – Non-Hearth Macrobotanical Data

Site	Site Name	Macro	Location
5BL2712	Rock Creek	Grasses, pigweed, milkvetch, goosefoot, prickly pear, purslane, bulrush, dropseed, and cocklebur	Various
5LR252	Spring Gulch	Goosefoot	Bottom of level IV
5LR349	Echo Cave	Pigweed, prickly pear, wild plum, wax currant, and chokecherry	Feature 1
5LR1085	Valley View	Chokecherry, wild plum, and prickly pear cactus	Various
5WL453	Johnstown	Goosefoot, sunflower, tansy mustard, mustard family, sedge family, grass family	Various
5WL1478	Agate Bluffs Complex	Dent corn, sunflower, wax currant, wild grape, and yucca	Various
5WL1479			
5WL1480			
5WL1481			
5WL1997	Three O' Clock Shelter	Chapalote maize	Feature 6

Data from Gilmore et al 1999, and Lawrence and Muceus 1980