THESIS

LANDSCAPE CHANGE AND STABILITY IN THE ABSAROKA RANGE, GREATER YELLOWSTONE ECOSYSTEM, WYOMING

Submitted by

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WE HERBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY NAOMI OLLIE ENTITLED, LANDSCAPE CHANGE AND STABILITY IN THE ABSAROKA RANGE, GREATER YELLOWSTONE ECOSYSTEM, BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS.

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Abstract of Thesis

LANDSCAPE CHANGE AND STABILITY IN THE ABSAROKA RANGE, GREATER YELLOWSTONE ECOSYSTEM, WYOMING

The archaeological record in the Upper Greybull of northwestern Wyoming is an integral part of landscape dynamics. A dominant force across this region is landslides, and over 60% of archaeological sites in this study were found to be associated with remnant landslide features. These relationships are analyzed at two different spatial scales to better understand landscape evolution in the Upper Greybull.

An investigation of site 48PA2811 shows the relationship between disturbance regimes, environmental change, and archaeological preservation at a local scale. This investigation included the documentation of surface and subsurface archaeological deposits, site geomorphology, physical and chemical soil analyses, site stratigraphy, and radiocarbon dating. Based on these analyses, over the last 3,000 years 48PA2811 has witnessed four periods of soil formation, followed by forest fire and rapid burial, and three separate human occupations. Fire and sedimentation resulted in the rejuvenation of biological communities, but chemical properties in the buried soils do not indicate dramatic changes in vegetation. Events at 48PA2811 parallel regional and even global-scale changes. Based on radiocarbon dates from burned A horizons at 48PA2811, the Medieval Climatic Anomaly may have had an impact on local environment at 48PA2811, leading to drought and fires.

From a regional perspective, across the Upper Greybull the relationship with landslide formations and archaeology offers potential for modeling landscape evolution in the region. The archaeological record indicates changes in landslide frequency and magnitude in the Upper Greybull since the Pleistocene. Through the Holocene, there has been an increase in the frequency of landslides accompanied by a decrease in size. The reason for this transition may be due to an increase in fires brought about by drier conditions in the late Holocene. It is also possible that humans played a role in the increase in disturbance regimes through time. The increase in landscape change in the late Holocene as indicated by the landscape history of 48AP2811 and regional landslides patterns is an important consideration in interpreting human use of mountain ecosystems through time.

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I thank both Dr. Chris Fisher and Larry for leading me to explore human and landscape interaction. An environmental approach to this thesis would not have been possible without the guidance of Dr. Gene Kelly. Gene Kelly and Suellen Melzer provided laboratory space and encouragement while I learned about soils. Suellen showed me virtual all I know about processing soils, and I thank her for her guidance and friendship. Colin Pinney and Dan Ruess from the Natural Resource Ecology Laboratory assisted me through total carbon and nitrogen analysis, carbon isotopes, and inorganic carbon, and answered many questions with patience.

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Last but not least I thank my family who have always been supportive of my ventures—my academic ones at least, and they have always allowed me to be myself.

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CHAPTER 1: INTRODUCTION, METHODOLOGY, AND CONCEPTS

Humans, both past and present, are an integral component of landscapes. The archaeological record itself is a mixing of the human component and natural components of a landscape. Often in archaeology the ultimate goal is separating processes in archaeological patterning in order to delineate the human behavioral aspects of the archaeological record (Schiffer 1983). This approach excludes the integration of human behavior with other natural processes which provides additional information about landscape change. In order to understand the evolution of a complex system such as a landscape, multiple factors need to be accounted for. This project uses archaeology, soil science, and geomorphology to track landscape changes at an archaeological site during the late Holocene. The site location is in the Upper Greybull River basin of central Absaroka Range of northwestern Wyoming. The processes occurring at this locale are important to regional landscape change and any future interpretations made on past human behavior in the region. Mass-wasting processes are particularly dominant across the central Absaroka Range and, in addition to a site specific investigation, the distribution of these features in relationship to archaeological sites is investigated across the Upper Greybull to develop a regional picture of the dynamics of landscape change through time and space.

Greybull River Sustainable Landscape Ecology

This study is an offshoot of the Greybull River Sustainable Landscape Ecology (GRSLE) project, a long-term ecological and archaeological project in the Central Rocky Mountains of northwestern Wyoming near the headwaters of the Greybull River. This region is referred to throughout the paper as the Upper Greybull. The archaeological field school, Department of Anthropology, Colorado State University, began investigations in the summer of 2002 and studies continue today. The GRSLE mission statement is as follows: "Integrating natural and social sciences to promote ecological and economic sustainability through transdisciplinary research, education and stewardship initiatives" (Todd 2007: www.greybull.org). Multiple studies that focus on a variety of relationships between natural and cultural systems encompassing a range of disciplines have resulted. Examples of theses from this on-going research include: anthropogenic rock structures (Kinneer 2007), development of an archaeological chronology for this mountain region (Burnett 2005), sourcing exotic lithic materials in the archaeological record (Bohn 2007), understanding motivations for historic land use (Mueller 2007), modeling temperature influence on archaeological site distribution (Derr 2006), and glacial geomorphology and archaeological associations (Reitze 2004). Other projects have included native plants and their medicinal uses (Hjermstad et al. 2004), fire history and forest belt change (Reiser et al. 2005), modeling possible human and animal migrations based on least-cost paths (Hurst et al. 2005), and many others. Over the course of five field seasons, some 250 archaeological sites comprised of more than 20,000 artifacts are identified in the Upper Greybull. The creation of an extensive database using a multi-faceted approach allows for a more enriched picture of this region's archaeology and the archaeological context. This thesis is a part of the story of this region's landscape history.

RESEARCH OBJECTIVES

The topic of this thesis was inspired by the discovery of a creek bank profile which today exposes 20, near-vertical, meters of stratigraphy in the form of deposition, erosion, soil formation, and cultural occupations. This exposure is part of archaeological site 48PA2811. The site was initially discovered in 2004 as a surface lithic scatter. Investigators decided to look over the cliff at the exposed creekbank and discovered a series of buried soils, a hearth feature, the partial forelimb remains of a *Bison bison*, and an additional cultural layer. The actively eroding cutbank required prompt research attention due to its fragile state and its potential catalog of information. With such an informative and complex view beneath the surface, the first intent was to identify the different deposits, how they were formed, why they were formed, and how this might help understand the integrity of the archaeology. The bulk of this study is thus site-intensive and concentrates on the landscape history of an archaeological site 48PA2811.

There are three main objectives for this study with a set of questions related to these tasks. The first goal uses an integrated landscape approach to investigate an archaeological site.

Objective 1:

Demonstrate how a multidisciplinary approach can be used to develop an environmental history of site 48PA2811.

Questions:

- How often has the landscape changed through times of human occupation?
- What processes are influencing this site?
- How can the identification of these processes help in reconstructing past environments before, during, and after times of human occupation?
- How has the archaeological record been impacted by these changes?

Objective 1 highlights the micro-environmental changes occurring at 48PA2811. Before tackling this feat, I acknowledge a voice of caution from Goldberg et al. (1993) who warn researchers that accounting for all of the various processes that result in the archaeological patterning may not only be unproductive but impossible. They continue that “the challenge is to link specific processes and causes to observed responses and effects, whether short-term or long-term” (Goldberg et al. 1993:viii). To answer the questions outlined above, I focus on analyses of the soils and sediments in which cultural items are found. For example, soil and stratigraphic mapping of the creek bank profile and texture analysis of soils are used to look at changes in depositional environments through time. The surrounding topography and geology are mapped to look at the larger geomorphic history of the site area and how this has influenced deposition and soil formation at the site. Laboratory analyses of soil samples taken throughout the creek bank profile are also used to look for proxies such as macro-fossils, organic matter, and carbon isotopes that may indicate a change in biota through time. Radiocarbon dating provides a timeframe for cultural occupation and the tempo of landscape change at this locale while archaeology provides a temporal marker of when occupation on a specific surface occurred.

Objective 2:

Demonstrate how the archaeological record can be used to assist other sciences in understanding the frequency and possible catalysts of landscape change in a mountain setting.

Questions:

- What types of landscape change dominate the GRSLE study area?
- Are these processes comparable to processes occurring in the surrounding regions?
- Does landscape change occur in patterns in time and space?

Objective 2 broadens the scope of observation from processes occurring at a site-specific scale to processes dominating the landscape across the Upper Greybull study area. Connecting the processes occurring at an archaeological site to the larger landscape enables these data to be put into a large context for regional comparison and pattern identification. Mass-wasting processes have occurred at a high rate throughout the region through time, and the archaeological record is put to use here to discuss any patterns in the distribution of mass-wasting remnants in time and space. The archaeological database created by the GRSLE project is matched with a landslide hazard database to identify associations between archaeological sites and mass-wasting remnants. The range and variability of the landslide/archaeology relationships is discussed and the use of projectile points as chronological markers on specific land surfaces is reviewed. A chronology of landscape change for the entire study area is not within the scope of this paper, but catalysts for regional landscape change are discussed based on patterns in the archaeological and landslide relationship.

Objective 3:

Demonstrate the importance of a methodological framework that incorporates ecological change in archaeological investigations.

Questions:

- Why is landscape change important?
- How can the archaeological record be incorporated into an "ecology of change" landscape view?

Objective 3 is ideological and aspects of this goal are peppered throughout this thesis. In this study I frame landscape change in terms of past human occupation, but landscape change is continuous. Disturbance regimes are important to prehistoric as well as contemporary land use. The contemporary human timescale does not take into account the history of landscape change, but the archaeological record can provide extremely valuable insights into past conditions. While these disturbance regimes may not occur at regular intervals through time, understanding the importance of these processes across a landscape should be of primary importance to land use planning. Disturbance is a key part of an ecological system and this includes human control of disturbance as well as human induced disturbance. Themes of this perspective are included in the following sections on methodology, in the discussion of geology, vegetation, animal populations, human populations and climate in chapter two, and in the final discussion in chapter five.

Organization of Thesis

The first chapter of this thesis outlines the goals and specific research questions. This chapter includes the organization of the thesis and a discussion on the methodology that frames this study. The second chapter is a “background” of the study area, which includes local geography, geology, climate history, and human history. I dislike the connotation of background, because in line with the landscape theme, each aspect of the landscape interacts with others and all aspects are dynamic. This second chapter then highlights the interrelationships between the broad categories as geology, archaeology, vegetation, and climate. Data specific to the study area are supplemented by ecological data from the surrounding region. Chapter 3 is the methods chapter. Methods include descriptive observation of the formation of archaeological site 48PA2811, soil and stratigraphic mapping, physical and chemical soil analysis, and radiocarbon dating. Spatial applications for investigating archaeological sites and mass-wasting features throughout the Upper Greybull through GIS are explained. Chapter 4 includes the results and interpretations of stratigraphic mapping, radiocarbon dating, and soil analysis of archaeological site 48PA2811. The chapter ends with an overview of archaeological sites and associated landforms in the Upper Greybull River study area. Chapter 5 is the final chapter and begins with a discussion on the questions put forth in Chapter 1 followed by a discussion connecting the results of this study in the Upper Greybull with larger regional landscape change occurring in the Middle Rocky Mountains and Northern Plains. Chapter 5 also includes final thoughts and future directions.

METHODOLOGY

The Concept of Landscape

The term landscape is used often in this paper and merits explicit definition. Use of the “landscape” concept varies in application from a social science emphasis

(Anschuetz et al. 2001) to a strictly ecological concept (Zimmerer 1994). The term landscape, when applied to archaeological investigations, refers to both human interactions and natural processes which are continuous and connected to a larger system (Wandsnider 1998). Figure 1.1 is a simple model for defining landscape. Three circles, biotic (soils, plants, animals, humans) systems, abiotic (topography, rocks and minerals) systems, and atmospheric systems are shown here and each overlaps, or integrates with the other as reflected in nature.

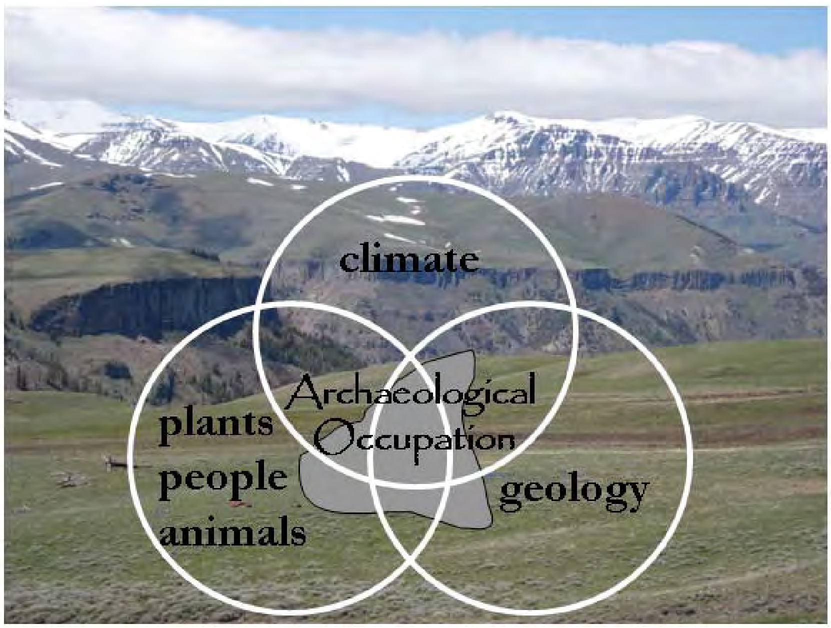


Figure 1.1 Generic model of the landscape concept.
(photograph courtesy of Larry Todd)

The landscape concept incorporates processes that occur over space and time. A definition of landscape which deals with these complexities is offered by Coones (1994). Coones (1994:5) defines landscape as “nothing less than the complex, interrelated and unified material product of the geographical environment, a seamless totality in which the immemorial processes of nature and the much more recent activities of mankind interpenetrate”. These “immemorial processes” refer to the modern landscape as actually a palimpsest of former landscapes but that every process that influences change on a landscape can not be recorded or interpreted. Each change has the potential to leave evidence of previous conditions allowing a landscape to hold a plethora of information, but not a complete record. Figure 1.1 is not an accurate reflection of the landscape concept. The landscape in Figure 1.1 lacks depth or dimension and the reality of landscape evolution. Figure 1.2 is an adjusted model to account for landscape change.

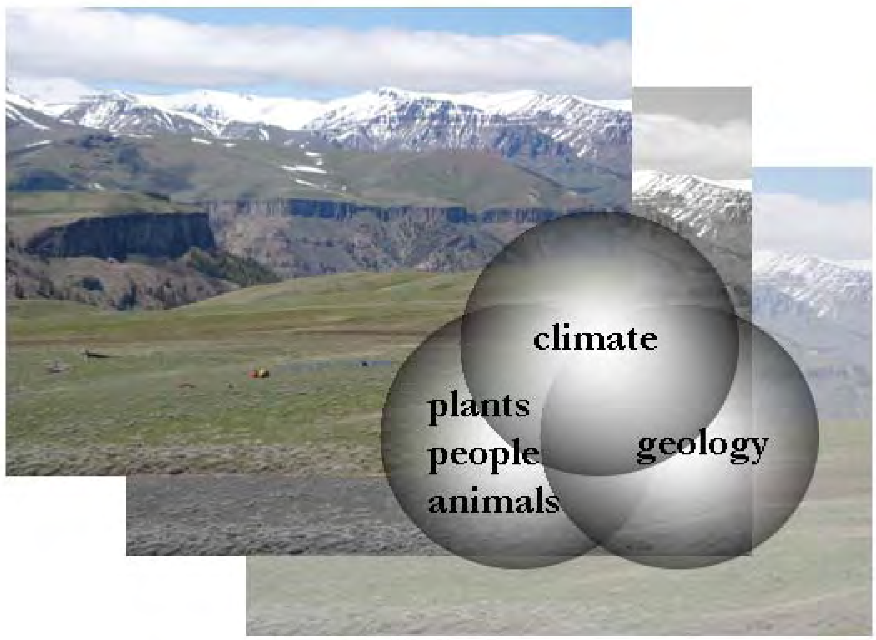


Figure 1.2 Adjusted model of a continuous landscape.

In this figure, a picture of today's landscape overlays two faded images of the same landscape. These images, which represent former landscapes, are faded to show that their complete reconstruction is not possible. Only two former landscapes are represented, but in reality the number of former landscapes nears infinite. The three spheres of interaction replace the circles to show a connection between the present interaction of these systems and past interactions. Each of these spheres contains a portion of a former landscape image. For example, archaeology from thousands of years ago or topographic features or rocks from millions of years ago may still remain and influence aspects of the modern landscape. Archaeologists must integrate multiple observations about different components of the landscape to develop a more accurate history of human and environmental interaction.

Multidisciplinary Studies

"Geologists describe sand as different than silt, in reality sand grades into silt" (Wilson 1974:iv).

It is impossible to approach landscape change without use of a multidisciplinary approach. Above Wilson (1974:iv) makes an analogy between soil texture and the boundaries between academic fields of study that he suggests are most often set out of convenience. When seeking to understand a relationship or process, especially when humans are a factor, many studies have a tendency to naturally transgress disciplines (Fisher 2005; van der Leeuw 1998; Wilson 1974). Often one discipline can not fully address a particular research question or problem. Wandsnider (1998:87) believes that due to the archaeological record's empirical nature, questions regarding its context and use are somewhat limited. Archaeologists are forced to ask different questions and seek out approaches and methods that allow them to take a different angle on a particular problem. Sometimes these questions lead to the creation of a new discipline. Wilson (1974) points out how there are many projects that can be pursued at the boundary areas between disciplines. The use of multidisciplinary approaches has resulted in the development of different fields of study and sub-disciplines which are a major part of the history of archaeology. Geoarchaeology, zooarchaeology, ethnoarchaeology, and environmental archaeology are a few examples of this trend.

Some of the most important anthropological questions are asked through a multidisciplinary approach. Rapp and Hill (1998:6) suggest that Charles Lyell might be the father of geoarchaeology. His book *Geological Evidence of the Antiquity of Man* (1863) was one of the first to formally address the question of our ancient past framing the problem in terms of geological principles and evidence. Multidisciplinary studies can also address some of today's most pressing issues, such as human's impact on the landscape both past and present (Fisher and Feinman 2005; Redman et al. 2004; van der Leeuw 1998; van der Leeuw and Redman 2002). Not all multidisciplinary studies can answer the big question of what it means to be human. The first multidisciplinary team was perhaps most interested in their local history. Trigger (1989:82) documents this team as: Jens J.A. Worsaae, the first professional archaeologist, biologist Japetus Steenstrup, and geologist J.S. Forchham, a multi-disciplinary commission assigned in 1848 by the Royal Danish Academy of Sciences. In their study of shell middens they were able to investigate changes in cultural behavior in the context of paleoenvironmental changes (Trigger 1989; see Morlot 1861:300-1). Trigger (1989) believes that this team's study provided a model at the time for work elsewhere.

Environment and Archaeology

Applying an environmental context to human behavior has taken a long, and in some phases, turbulent road. In his book on *Archaeology as Human Ecology*, Butzer (1982:4) laments over approaches in archaeology some 100 years after the work of

Worsaae and company, “what remains poorly articulated is the equally fundamental environmental dimension.” In his view, archaeological approaches of the 1970s lacked a conceptual framework to deal with the environment, instead using the environment as a static backdrop. Ecology however, is interested in the *relationships* between organisms and their environment (Keller and Golley 2000:9), and for Butzer (1971, 1982:5) and many others (for examples see Hawkes et. al 1982; Kelly 1995) the environment has an active role in cultural behavior.

The ecological emphasis, proposed by Butzer (1982), was applied to archaeological method. Schiffer (1972) delineated an approach to the formation of the archaeological record, integrating methods from earth science and archaeology. *Formation Processes of the Archaeological Record* (Schiffer 1987), was the first book to set up a framework for the treatment of both cultural and natural processes. The focus of Schiffer’s (1987) approach is identifying the integrity of an archaeological site with a concern for assemblage context, condition, and spatial distribution. Because sites are influenced by human and animal agents, as well as biological and mechanical processes, a wide variety of analytical techniques addressing the interaction of various cultural, biological, climatological, and geological processes is called for before behavioral interpretations in the archaeological record can be advanced (Schiffer 1983, 1987).

The themes of human ecology and methods to investigate formation processes come together in the practice of environmental archaeology, the study of paleoenvironments as human habitats (Dincauze 2000:20). Environmental archaeology is an extremely broad approach that encompasses sub-disciplines like geoarchaeology in terms of shared research goals and methods. There are many practitioners and examples of studies that would fall within the category of environmental archaeology, but the definition and goals for environmental archaeology outlined by Dincauze (2000:17-18) sum up the approach rather well. The three goals are outlined below.

The first goal of environmental archaeological is to describe and understand environments of the human past. Essentially, this is the first objective outlined for this thesis, the nuts and bolts of an environmental archaeological study. Environmental archaeological studies rely on some form of proxy data in paleoecological reconstruction. Proxy data are “observable data used as surrogates for conditions not directly observable” (Dincauze 2000:30). Paleoenvironmental proxies used in this study include physical and chemical properties in soils and also topography and landforms that indicate geomorphic change.

The second goal of environmental archaeology is to seek knowledge of the nature of *H. sapiens* and specifically the inherent potential and limitation of the species (Dincauze 2000:17). Dincauze refers to *H. sapiens*, but environmental archaeology is applicable to pre-sapien species as well. This second goal emphasizes human ecology, and it is echoed by Evans and O’Connor (1999:1) who state that “above all, people are a part of ecosystems, and the role of the biophysical environment in offering challenges and opportunities to them is fundamental.” Ethnographic evidence of hunter and gatherers shows that the resource structure of an environment is important to variables influencing subsistence patterns and settlement systems (Binford 2001; Kelly 1995). While this is one of the most intriguing and controversial aspect of understanding of human adaptations, it is one I do not model for extensively in this study.

The third goal centers on the need to build into the fabric of our daily lives an awareness of the global consequences of our activities (Dincauze 2000:18). Goal number three emphasizes the impact of humans on the landscape and calls for the researcher to make studies relevant to populations today.

An environmental archaeological approach can incorporate numerous disciplines with a wide variety of methods. This study uses methodologies and methods from geomorphology and pedology to address the broad goals of an environmental archaeological approach. Pedology is a natural avenue to explore landscapes. Soils are an environmental continuum between different components of the earth, providing an interaction zone. Many studies that integrate soils embrace Jenny's (1941) theorectical approach to soil formation. This approach predicts that any one property of soil is a function of climate, biota, relief, parent material, and time. The anthropogenic influence is an additional factor, receiving more recent attention. Soils are important to archaeological investigation because their properties can reflect environmental change and geomorphic environment (Ferring 1992; Holliday 1992). Put another way, Margaret Berry (from Birkeland 1999:1) states that "soils can be used in evaluating landform evolution and age, landform stability, surface processes, and past climates." Holliday (1992) emphasizes two different fields in soil science; the field of pedology which is the study of soil genesis and morphology; and soil geomorphology, which looks for relationships between soils and landscapes. Both aspects are used in this study.

This study also borrows heavily from geomorphology. Geomorphology is the study of processes that induce a change, either chemical or physical, in the materials or forms at Earth's surface (Ritter et al. 2002:2). Geomorphology adheres to the principles of uniformitarianism, a geologic doctrine that processes acting on the earth today are the same as those in the past and can account for all geological features present on the earth. Thus, intensive analysis of the structure of the sedimentary record within site provides site formational data (Butzer 1971, 1982). Geomorphology, like the study of soils, can be used to connect local formations with regional processes.

The Influence of Scale on Observable Phenomena

There are two additional concepts that dominate this study. The first is the concept of scale. Environmental proxy data, as with most data, are scale dependent. Landscape ecology gives particular emphasis on patterns and processes that are scale related (O'Neill and King 1998: 6; Turner et al. 2001), but the recognition for scale is important to practically all investigations. Figure 1.3 shows the influence of scale, both spatially and temporally on observable phenomena. Different processes are visible at different temporal and spatial scales; i.e., are scale dependent. Evans and O'Connor (1999:31) use factors in soil formation (Jenny 1941) to discuss the influence of scale. At the order level in soil taxonomy (the highest level in the taxonomic hierarchy) soil-type is related to climate, but within a particular climatic zone, other factors become more important to variations in a soil. The top-down control of climate becomes of less importance as local variation is also influenced by bottom-up controls such as lithology and topography. Variables used to explain patterns on a specific spatial or temporal scale are not as applicable at different spatial or temporal scales (Kornfeld and Osborn 2003:9).

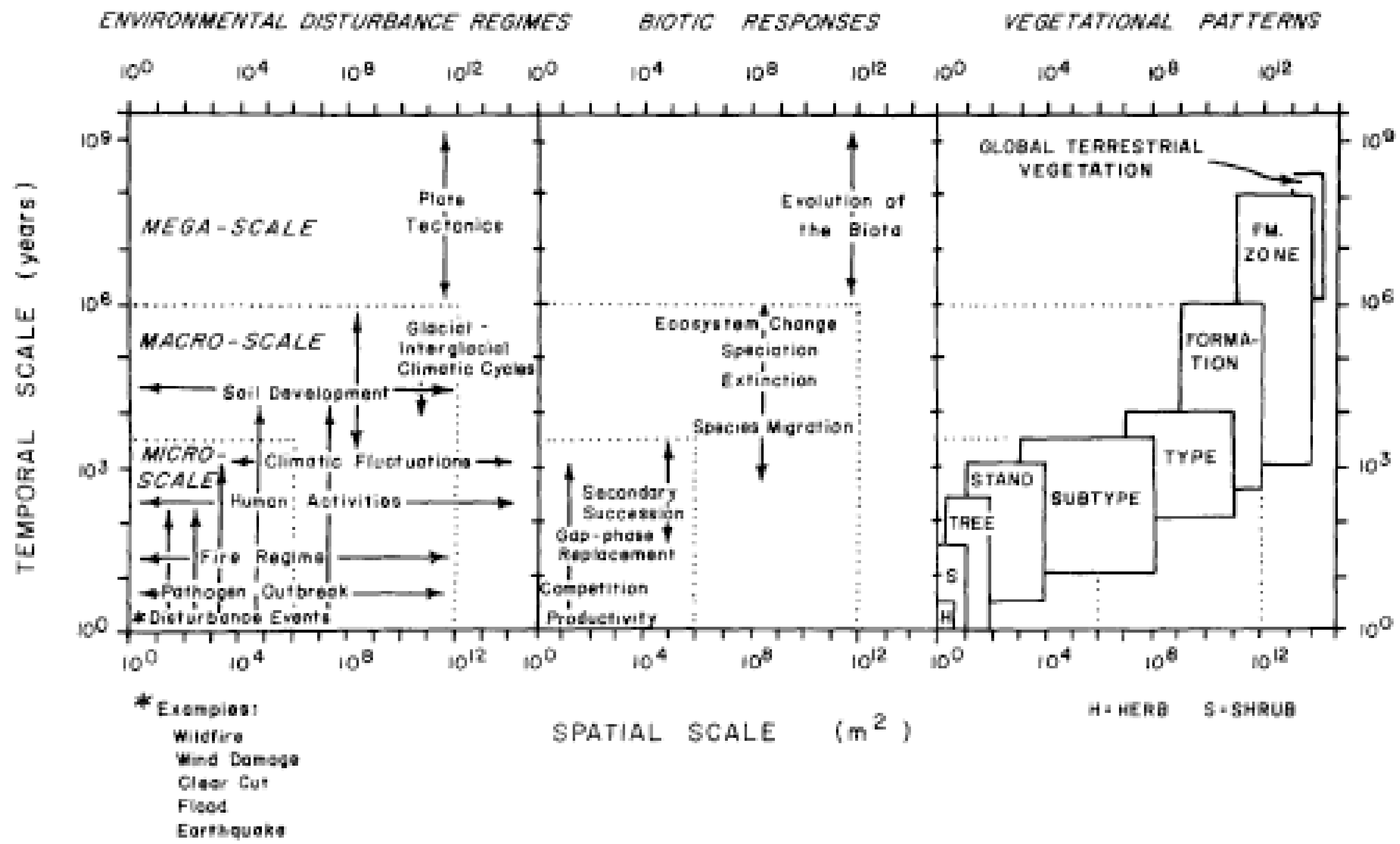


Figure 1.3 Environmental disturbance regimes and biotic responses across space and time (from Delcourt et al. 1983:155).

While this study focuses on processes at the micro-scale in both the temporal and spatial realm, to determine if these processes are strictly local phenomena or not, I investigate processes occurring at a regional scale. Referring to Figure 1.3, glacial and interglacial climatic cycles are considered macro-scale disturbance regimes and biotic responses are ecosystem change, speciation, migration, and extinction. But these macro-scale disturbance regimes may also influence micro-scale disturbance regimes. For example, climate change can impact local drought patterns which increase the chance of wild fires at a local scale. Processes that take place across the Upper Greybull study area and shape the landscape history are influenced by a range of factors including local, or micro-scale phenomenon, to regional, and global, or macro-scale phenomena. The scope of observation in later chapters is widened to a regional scope in an attempt to parse out larger factors that might be contributing to landscape change at a local scale.

Disturbance Regimes in Ecological Theory

Disturbance is the second concept that dominates this study. Disturbance events are presented in Figure 1.3 under 'environmental disturbance regimes'. These events are considered the most micro of scales and are often observable at the human time-scale. The corresponding biotic response to disturbance regimes is productivity. Post-fire studies in Yellowstone National Park provide a poignant example of the biotic response to disturbance. Studies conclude that blazes maintain the ecosystem and increase resource richness (Despain 1978; Turner et al. 2003). The disturbance regimes of most interest in this study are mass-wasting events and more subtle sedimentation regimes.

Fire is considered an important catalyst for these processes. The relationship between fire and sedimentation will be discussed in further detail in following chapters.

Mass-wasting events play an important role in maintaining biological diversity (Geertsema and Pojar 2005). These events alter topography and stream channels, redistribute soils, turn back the clock to early stages of pedogenesis, promote new vegetation and/or change vegetation distributions, and create lakes (Bailey 1971; Geertsema and Pojar 2006). The diversity in landscape responses provides important habitat for many organisms and undoubtedly was important to human groups that used local resources. Mass-wasting and the landscape change that results from these events have a lasting impact on archaeological preservation.

While disturbance regimes are important in resource distribution and thus, in theory, would have played a role in human decisions about the landscape, humans also play a role in producing disturbance regimes and landscape change. While North American ecosystems have been inhabited by hunter and gatherer groups for over 10,000 years, there is a lasting notion that these people had little impact on the landscape (Krech 1999). For prehistoric agricultural societies, erosion and sedimentation patterns provide an important record of the anthropogenic influence of farming activities on the landscape (Hall 1990; Woods 2004). It has also been suggested that the opening of North American grasslands, and their preservation was possible only by regular burning by North American Indians (Anderson 1990; Sauer 1950). The influence of indigenous groups on the Greater Yellowstone Ecosystem is difficult to assess, though the use of fire in by groups inhibiting the Greater Yellowstone Ecosystem may have been a regular practice (Janetski 2002).

Disturbance regimes, both natural and human-induced, are not fully recognized or emphasized in environmental archaeological studies. In Butzer's (1982:8) outline of an approach to the human-environment relationship he refers to the "equilibrium state". This concept relies on negative feedback, the forces that dampen potential change, help a system readjust to positive feedback, or the forces that enhance change. In other words, a system can be pushed and pulled to alternative states, but has a tendency to fall back to equilibrium. This echoes a traditional ecological philosophy proponed by Clements (1916), which contends that systems have a natural tendency to cling to their components. In its most literal definition, this concept cannot apply to systems where transformations occur.

The 'new ecology' approach coined by Zimmerer (1994) emphasizes "disequilibria, instability, and chaotic fluctuations in biophysical environments". New ecology provides a theoretical framework for addressing change and dynamic interactions, and this framework can be applied to many different systems. Gunderson and Holling (2002) outline the unifying theme "Panarchy," which is designed to fit human and natural systems. Panarchy outlines four functions of ecological principle. This model is Figure 1.4. The first two are exploitation and conservation. The second are collapse and reorganization. Any given systems may not go through all of these functions.

The Panarchial cycle is scale related. A system may go through all phases over the course of a human generation. Alternatively, a system may not appear to change at all within the human time-scale. Redman et al. (2004:3) (see also Redman and Kinzig 2003) urge the researcher to ask the following question regarding the behavior of a system; does change occur in the form of a cycle that repeatedly leads the system back to a state relatively similar to the one it started as, or does the system pass a threshold value so that it does not return to former conditions but assumes distinctly new characteristics? These questions and their answers are determined by the time scale of observation.

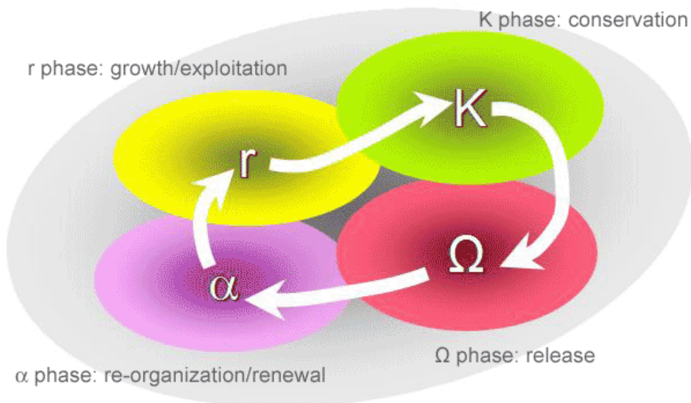


Figure 1.4 The adaptive cycle. (from the Resilience Alliance 2007)

The Upper Greybull study area fits a dynamic ecosystem model. Observable processes within the Upper Greybull study area indicate a tendency toward change; both cyclic and transformational. Today, evidence of change in forest belt takes the form of groups of dead trees or “ghost forests” (Reiser et al. 2005). Pine-beetle infestations and forest fire indicate change will continue. Ancient landslide deposits indicate complete transformations in topography across the mountainside. This thesis addresses some of the more transformational changes in topographic shifts and how these changes impact local cycles of landscape change.

This chapter discussed the research objectives, the methodological outline of an environmental archaeological approach to landscape change, and defined the concepts important to this study: landscape, disturbance, and the influence of scale on observable phenomena. The landscape is a dynamic system and the following chapter provides a historical discussion of the Upper Greybull landscape. Geologic, biotic, and climatic histories are used in the following chapter to provide a context for the processes that occur across the system both today and in the past. The Upper Greybull River is by no means a separate system from the surrounding region and to show the connectiveness of the landscape, the following chapter discusses environmental change in and around the Upper Greybull. The archaeological record is combined in the historical discussion.

CHAPTER 2: THE ABSAROKA LANDSCAPE

“As any thespian knows, the stage set is not passive; it constrains, and sometimes even inspires, particular actions and responses” (Dena Ferran Dincauze 2000:xvii, speaking of ‘environment’).

Humans have a relationship with their environment, and a description of the study area’s landscape is required. This chapter includes an overview of geographic location, biotic communities, geology, and climate of the Upper Greybull study area. The Absaroka landscape has changed slowly and sporadically through geologic time and through human history. These changes are emphasized in this chapter and the impact of change in one aspect of the landscape, such as the geologic sphere, is not separate from changes in other aspects of the landscape, such as the biotic sphere. This interconnectedness is emphasized.

Geography

The setting for this study is northwestern Wyoming in the central Absaroka Range. The Absarokas are an eastern sub-range of the Rocky Mountain chain stretching 240 km between Montana and Wyoming. The following features border the Absaroka Range: to the north is the Snowy Range of Montana, to the east is the Bighorn Basin plateau, to the south is the Wind River Basin, and to the west is the Yellowstone plateau. Elevation change is most abrupt from the Bighorn Basin to the eastern flank of the Absarokas. Francs Peak is the highest peak in the range measuring 4,009 meters above sea level (masl). Elevations drop to less than 2,000 masl in the Bighorn Basin. Within the Absaroka Range, topographic change can be sudden and dramatic, characterized by broad uplands, steep valley slopes, and narrow floodplains (Breckenridge 1974:10). Figure 2.1 is a nested map of the general study area. Elevations are reclassified to 500 m intervals.

Hydrology

The study area is defined by the drainage basin of the Greybull River. Because the Absaroka Range is located on the eastern side of the Great Divide, the Greybull River is part of the Yellowstone-Missouri river drainage system. The Greybull River flows north from its headwaters in the high peaks of the Absarokas before making a curve east into the Big Horn Basin. The Greybull River's discharge is primarily from snowmelt. The river's peak is during summer reaching 1,000 cubic feet per second (cfs) in June and July of 2006 while December through March discharge drops to 100 cfs (USGS Real-Time Water Data for the Nation).

Many first and second order tributaries flow into the Greybull River. The Wood River is the main tributary to the Greybull River. These tributary basins and the surrounding uplands are the target for archaeological study. This thesis centers primarily on the archaeological site 48PA2811, located along the tributary Piney Creek. Piney Creek is a northern tributary to the Greybull, and its headwaters originate on the eastern slopes of Carter Mountain (Figure 2.1). Site 48PA2811 sits on the northeast bank of Piney Creek. The Piney trailhead is located in the Jack Creek campground. The hike begins with the crossing the Greybull River and following the trail for approximately seven kilometers traversing slopes and mass-wasting deposits.

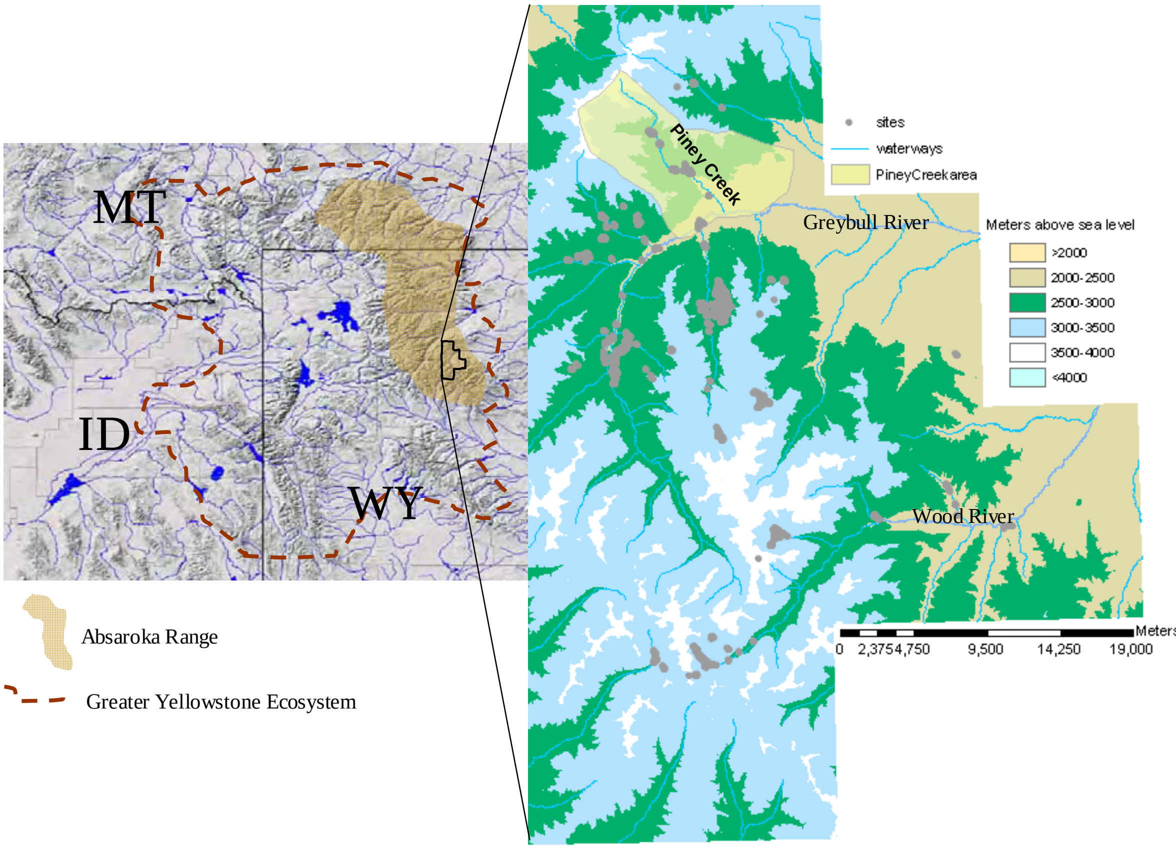


Figure 2.1 Location of Upper Greybull study area.
Base map from http://seamless.usgs.gov/website/seamless/viewer.php. Elevations presented in 500 m intervals based on a digital elevation model from U.S. Geological Survey EROS Data Center (1999). The grey clusters indicate mapped artifact concentrations.

Land Use and Ownership

The Upper Greybull study area is protected by federal mandates. Roughly 70% of the study area's land is designated wilderness. The Washakie Wilderness was established in the 1964 Wilderness act. The Shoshone National forest makes up the remaining portion of the study area. This national forest is the first federally protected forest signed into law in 1891. Due to these mandates, the Upper Greybull River is largely undeveloped. The few exceptions are campgrounds and access roads to the Jack Creek trailhead and the Gold Reef tunnel, a historic mining camp (Mueller 2007). Privately owned land is confined to lower parts of the Greybull River where the mountains grade into the basin, though a handful of private land tracks do exist. Human impact throughout the area includes hunters, pack animals, and recreationalists, as well as a history of domestic grazing. Presently the only economic industries that exist are an oil field and a few small oil wells and two ranches. These businesses are located on state, Bureau of Land Management (BLM), or private land bordering the national forest area. Two local ranches actively graze cattle in the Absarokas. The closest community to the study area is the historic town of Meeteetse about 25 km away, and the historic mining town of Kirwin is located on the Wood River.

The Upper Greybull and Greater Yellowstone Ecosystem

The Upper Greybull River study area is on the fringes of a larger, unique, and active landscape, the Greater Yellowstone Ecosystem (GYE). The GYE has somewhat mutable boundaries but in general it expands over northwestern Wyoming, southwestern Montana, and eastern Idaho, encompassing an area of over 2,023,420 ha (20,234 km^2) (Cannon and Cannon 2004; Craighead 1979). The GYE was originally classified as the range of grizzly bears (*Ursus arctos horribilis*), but the wide-range of Yellowstone's grizzly bears links most of the habitats and associated species characteristic of the GYE (Clark et al. 1999). The Greater Yellowstone Ecosystem therefore is a system of interacting biotic and abiotic components. While grizzlies are still key characters of the ecosystem the GYE designation connotes particular features of North American wilderness area, geological history, and ecosystem dynamics which are further elaborated below.

Four seasons are distinct in the region. Storm patterns for the area are variable due to the influence of large mountain chains. Western portions of the GYE are characterized as winter wet/summer dry and the eastern portions are winter dry/summer wet (Whitlock and Bartlein 1993). The northern part of Yellowstone National Park experiences higher summer and annual precipitation as a result of convectional storms associated with summer monsoonal circulation, while the rest of the Park is relatively dry and under the influence of the northeastern pacific subtropical high-pressure system.

The Upper Greybull is considered within the eastern portion of the GYE and is typically drier. Annual precipitation from the Sunshine 3NE weather station, just north of the study area, is 35.2 cm (Western Regional Climate Center 2005). Winter temperatures recorded at this station range from -13.33˚C to 0˚C while summer temperatures average 18˚C. Local factors of elevation and aspect create variability in areas of snow accumulation and snow-free areas. The elevation range for the study area is between 2,190-3,450 masl and precipitation generally increases with the increase in elevation. Site 48PA2811 is at an elevation of around 2,550 m with a southern-facing aspect. These factors can determine in which areas runoff will occur first. For example, 48PA2811 was snow-free in late May of 2005 while across the Greybull River, directly south of the Piney drainage, snow prevented field access on north-facing drainages. The site experienced a snowstorm during this field foray, an example of the unpredictability of weather with the onset of spring.

While the high altitude and northern latitude of the GYE limits animal species richness, there is a great abundance of certain species in this region. Elk (*Cervus canadensis*) are particularly common and the largest known herd is located in the GYE

(Clark et al. 1999). Preservation efforts have allowed for many other animals, including carnivores, to inhabit the region. The GYE provides a unique opportunity to view the dynamics of predator/prey relationships, which are not observed at this latitude in many other areas of the world (Clark et al. 1999). The region is populated by grizzly bears as well as a full entourage of other native carnivores including wolvorene (*Gulo gulo*), gray wolf (*Canis lupus*), coyote (*Canis latrans*), black bear (*Ursus americanus*), and mountain lion (*Felis concolor*) (Clark et al. 1999). Other animals include pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), whitetail deer (*Odocileus virgninianus*), moose (*Alces alces*), bighorn sheep (*Ovis canadensis*), and bison (*Bison bison*), among numerous small mammals and birds.

The GYE frames well the interaction between the systems of a landscape. The region is known for the large expanses of coniferous forest, and species within these forests are divided into elevational zones (Knight 1994). Below the forested zone, vegetation is dominated by semiarid sagebrush shrublands with basin big sage (*Artemisia tridentata* spp *tridentata*) and bluebunch wheatgrass (*Agropyron spicatum*) (Despain 1990). Alpine tundra above the upper timberline has a large number of species from the arctic tundra and species that have evolved from subalpine floras. Between these extremes are the two forested zones: the lower timberline (1,950 masl) dominated by Douglas-fir (*Pseudotsuga menziesii*) and upper timberline (3,050 masl) dominated by Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) (Despain 1990; Pierce et al. 2003). Areas underlain by fine soils are generally covered with shrublands or grasslands that provide forage to support populations of large mammals such as elk and bison (Pierce et al. 2003). Montane zones provide winter range and subalpine and alpine zones provide summer range.

In the GYE there is a strong connection between vegetation communities and geologic substrate (Despain 1990). Sagebrush-grasslands are underlain by glacial deposits. In general, limestone supports limber pine (*Pinus flexilis*), Douglas-fir (*Pseudotsuga menziesii*), and aspen (*Populus tremula*), depending on moisture availability; however, these species occur on volcanic parent material in the Upper Greybull. Andesite supports spruce/fir, and rhyolite plateaus are dominated by lodgepole pine (*Pinus contorta*). Geological influences are also apparent in soil type and the vegetation response to the Yellowstone fire of 1988. Rich soils developed from andesitic and sedimentary substrates have produced herbaceous growth and sparse tree seedlings while the weaker soils derived from rhyolitic substrates are covered by dense *Pinus contorta* seedlings (Pierce et al. 2003:319). Local factors also influence vegetation distribution such as aspect, slope, elevation, and water availability and are explained below.

In the Upper Greybull there is a lack of notably large tree stands observed in the GYE (especially in Yellowstone Park). This reflects local conditions of steep slopes and a dry, porous substrate (Thilenius and Smith 1985:7). The modern vegetation distribution is also considered elevation-based with a gradual and patchy transition from Great Basin shrub to alpine vegetation (Thilenius and Smith 1985). Vegetation surveys along the slopes of Carter Mountain, a long northeast-southwest trending ridge on the eastern edge of the Absaroka Range, find isolated groves of *Picea engelmannii* and *Abies lasiocarpa* and some scattered *Pinus flexilis* (Thilenius and Smith 1985:1). These groves are confined to mesic slopes along watercourses. Between the groves, on the ridges and hillcrests, is shrub-grass vegetation dominated by *Artemisia tridentate* (Thilenius and Smith 1985:1). Perennial forbs are the dominant life-form in all the community types (Thilenius and Smith 1985:7). Meadow tundra and exposed bedrock dominates elevations above 3200 masl. Thilenius and Smith (1985:7) point out that Carter Mountain's current vegetation may not be an accurate reflection of pristine alpine life. This region has a long history of domestic sheep grazing, and Thilenius and Smith (1985) believe that this has influenced floristic composition leading to similarities, rather than variability in alpine community types.

Variations in vegetation can be linked to the soils that support these communities. Soils in the Upper Greybull are generally weak in development (little pedogenesis). There is, however, extreme variability on a local scale due to differences in topography, time, biota, and altitude-based climate differences. The U.S. Soil Survey data are not complete for this area and soil data are only available on the 1:500,000 scale. At this scale, there is a dramatic change in soil type moving from the alpine zone to the basin. Soil differences due to climate and surface geology changes are reflected at this scale, but local variability in microenvironment is missed. Soils throughout the area are generally thin but topographic pockets for deposition, such as at site 48PA2811; provide deposition and preservation of past soils and cultural materials.

A few specific studies look at soil development on and near Carter Mountain (Breckenridge 1974:48; Thilenius and Smith 1985). Breckenridge (1974) assigns the soils of Wood River, the major tributary of the Greybull, to the suborder Andept on the basis of pyroclastic parent material (Breckenridge 1974:48). Soils are assumed to be cold enough to be placed in the Cryo great group (mean annual temperature in the range of 0-8˚ C) and in the Pergelic soil subgroup (mean annual soil temperature 0˚C) (Thilenius and Smith 1985:3). Breckenridge (1974:48) classifies soils in the study area as cryandepts with mollic epipedons (surface horizon containing over 1% organic matter; structure is not massive and hard; base saturation over 50%). Thilenius and Smith (1985:3) identified soils from three different soil orders: Entisols, Inceptisols and Mollisols; and further divided these in seven soil subgroups. At this more local scale, differences in soils are largely attributed to microenvironmental factors. These factors influence specific characteristics of the soil and will be discussed in great detail for site 48PA2811 in the results chapter.

The present-day distribution of plants, animals, soils, and landforms in the Greater Yellowstone Ecosystem and the Upper Greybull River are not replicas of past communities. To show the dynamics of these systems the following discussion outlines the geological history, surface geological processes, climate history, archaeological, and environmental history at different time scales.

A LANDSCAPE HISTORY

Geology

The Absaroka Range is a geologically young mountain range with an active history. Their construction is considered a jumble of volcanic formations or a "volcanic pile" (Breckenridge 1974) also known as the Eocene Absaroka Volcanic Supergroup (AVS) (Smedes and Prostka 1972). This volcanic field is the largest of many volcanic fields that were created during major widespread Eocene volcanism in the Rocky

Mountains. The Absaroka Volcanic Field is constructed of three main geologic groups that are composed of multiple volcanic formations (Smedes and Prostka 1972). These formations cover the north and east portions of the GYE. The Washburn Group (largely middle Eocene) is the oldest and is only present in the northern portion of the field and will not be discussed. The two remaining groups are present in the central southern Absarokas, where the Upper Greybull study area is located. These are the Sunlight Group (middle Eocene), which lies above the Washburn Group, and the Thorofare Creek Group (middle to upper Eocene), the group most dominant to the study and subsequently the youngest of the groups (Smedes and Prostka 1972:4).

There are older formations that exist below the Absaroka volcanics. The stratified rocks of the AVS rest unconformably on rocks ranging in age from Precambrian to Paleocene (Smedes and Prostka 1972). In the Upper Greybull study area, the earliest formation observable is the Early Eocene Willwood Formation, a series of variegated siltstones, sandstones, and conglomerates (Breckenridge 1974:8). On the eastern flank of the Absaroka Range, just north of the study area, this formation crosscuts older Cretaceous formations (Decker 1990:7). Within the study region, Dollar Mountain, an uplifted block of Paleozoic sedimentary rock, provides an anomaly between volcanic formations (Reitze 2004; Wilson 1964). Other formations that occur in the study area are various volcanic intrusions that have cross-cut the bedded volcanic rocks during the turbulent Eocene. Intrusive events in the Kirwin and Gold Reef areas have provided some opportunity for mineral exploitation (Mueller 2007; Rouse 1940).

The AVS forms the bedrock and the topography of the study area, but only a few specific formations are visible in the study area. This has created some confusion in correlating formations and stratigraphic and structural relationships (Decker 1990:3). In general, the volcanics that make up the AVS are andesitic, basaltic, and dacitic volcaniclastic rocks (Smedes and Prostka 1972). The term volcaniclastic, defined by Decker (1990:10), refers to both reworked volcanic deposits and primary pyroclastic rocks. This is a good blanket word to account for the mixing of new pyroclastic units and lava flows that reworked earlier eruption products. Formations that are unique to the study area include the Wapiti Formation of the Sunlight group. This formation overlies the Willwood Formation and is considered the basal volcanic unit (Smedes and Prostka 1972:24). The Wiggin's formation, the youngest of the Absaroka volcanic formations, is the most widespread deposit in the Upper Greybull and is made up of intercalated flows, tuffs, and breccias predominantly of andesite (Breckenridge 1974:8). The wide range of textures and compositions of the Eocene formations has created a landscape susceptible to high amount of mass-wasting.

Mass-wasting and Surface Geology

More recent geologic activity is evident with the presence of mass-wasting features that dominate surface geology in Upper Greybull River study area. Just over 150 different types of landslides occur in the study area (Wyoming State Geological Survey and the Water Resources Data System 2001). Table 2.1 lists some categories that will be referred to and abbreviations that will be used throughout this paper. While some features listed, for example rock glaciers and alluvial fans, are not considered landslides, these were included in the database and are active land surfaces. In the Upper Greybull, landslide types are often a combination of slope movements made up of a combination of basic forms.

Table 2.1 List of mass-wasting types common to the Upper Greybull and abbreviations. From Wyoming State Geological Survey and the Water Resources Data System (2001).

Abbreviation	Landslide type		
Av	Avalanche chute	Ms	multiple slump (bedrock, debris, or earth)
Blsl	block slide (rock or earth)	Rf	Rock fall
Blstrm	block stream	Rff	rock fragment flow
Bs	bedrock slump	Rg	rock glacier
Bs/ds	bedrock slump/debris slump	Rga	rock glacier—active
Dav	debris avalanche	Rgi	rock glacier—inactive
Df	derbis flow	Rs	rock slide
Dlef	debris-laden earth flow	S	Slump
Ds	debris slump	s/f	slump/flow complex
Ef	earth flow	Solif	Solifluction
Es	earth slump	Tf	talus flow
F	flow (earth or debris-laden earth)	Ac	alluvial cone
Frf	flowing rock fragments	Af	alluvial fan
M	Multiple	Cc	colluvial cone
Mblsl	multiple block slide (rock or earth)	Qal	Quaternary alluvium
Mdf	Multiple debris flow	Qg	Quaternary glacial deposits
Mf	multiple flow (earth or debris-laden earth)	Qlg	Quaternary landslide and (or) glacial deposits
Mrff	Multiple rock fragment flow	Qt	Quaternary talus
Mrs	Multiple rock slide	Sw	slope wash

Most features in the Upper Greybull study area are considered a combination of types of mass-wasting, and because there are so many different combinations of types, not all can be listed separately. Table 2.2 lists dominate landslide types that occur in the Upper Greybull study area. In this table specific landslide types are combined into more general categories. The general landform is listed in the first column followed by a second column of specific landslide types. For example, features listed as slumps can include ms/mf, or msblsl, but their primary listing description is a slump based on the

Wyoming State Geological Survey and the Water Resources Data System (2001). The total area covered by such events and the frequency of each mapped feature in the Upper Greybull study area are listed in Table 2.2.

Table 2.2 Area and frequency of mass-wasting related surfaces in the Upper Greybull

Landform	Examples	Frequency	Area km^2
Slumps	ms, msblsl, older ms/mf, s/f	290	109146
Blockslides	mblsl, blsl/ms	52	34010
rock slides	mrs/Qt, mrs/mf , rf	188	29492
talus features	mtf/rg, tf, tf/Qt	142	22487
glacial features	mrg/Qg, rgi, rg/Qt	55	14924
alluvial formations	ac, af, af/df, maf	95	9465
Solifluction	solif, solif/mf	24	3665
Flows	df/sw, df/av, fsel, mdf, mf/sw	234	3458
older slide masses	older slide masses	3	2192
Sheetwash	sw/mdf	3	527
Avalanche	av/df	3	81
Totals		1089	229446

The most dominant type of mass-wasting feature in the study area is the slump or combination slump event based on area, frequency of occurrence across the landscape, and field observation. Breckenridge (1974) notes that in the Wood River, slump blocks that are generally low-energy, high-volume slides, cover the most area. According to Breckenridge's (1974) observations, earthflows run second to slumps in the total volume of material moved. These are high-energy events identified by their hummocky surfaces which often contain small closed depressions occupied by sag ponds (Merrill 1974:65). Values in Table 2.2 do not indicate that the total area covered by flow features is as great as other features listed, but it is combination slump/flows that cover much of the area and these features are included with the slump values. Figure 2.2 is a map showing the distribution of some of the more common mass-wasting features. These include slumps, debris flows, rockslides, slump/flows, and glacial features. Slump/flows dominate the eastern slope of the Absaroka Range where the mountains meet the Big Horn Basin. Some slump/flow features contain many surface archaeological sites, indicated in as reddish dots in Figure 2.2. This relationship will be drawn upon more in chapter four.

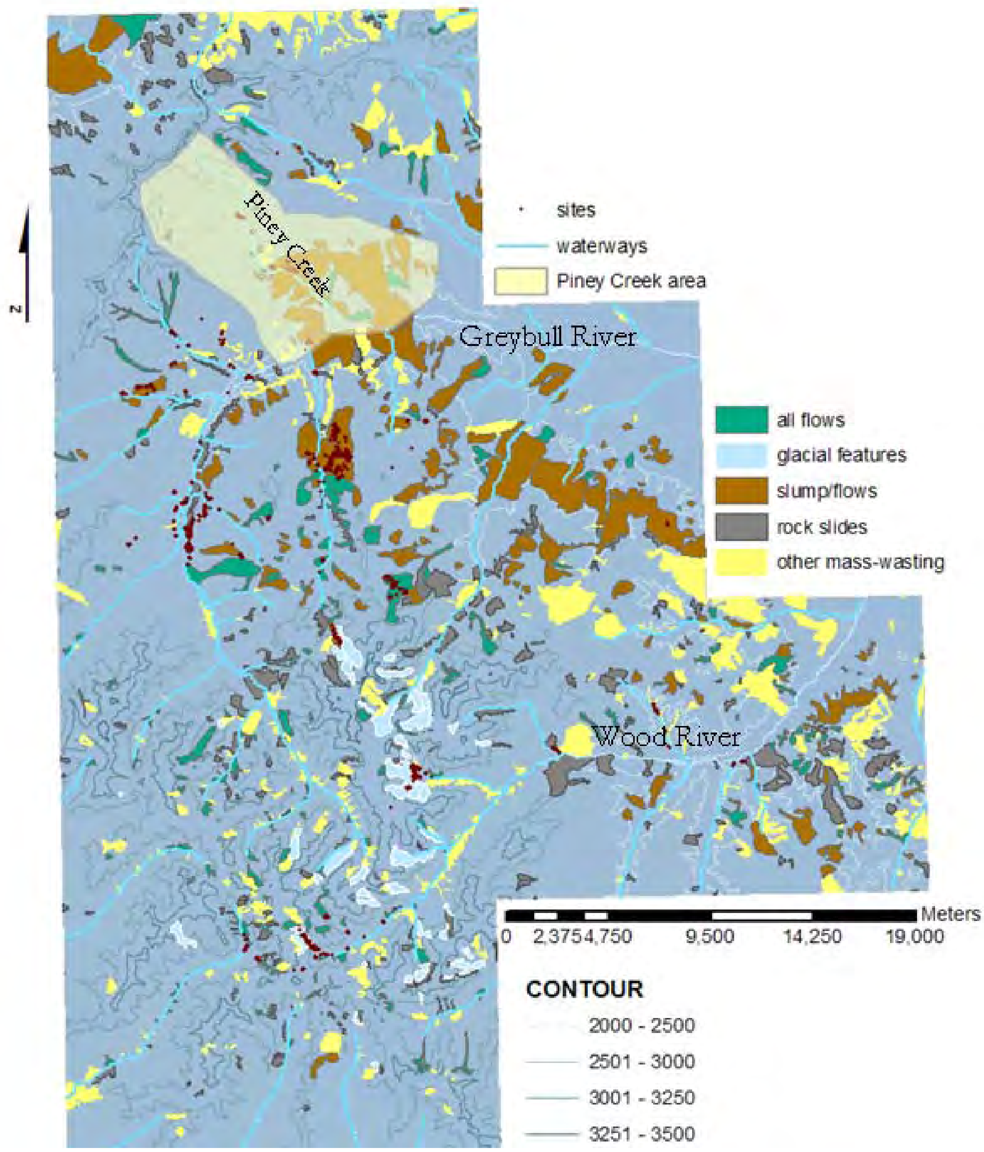


Figure 2.2 Mass-wasting features mapped across the Upper Greybull.
Landslide data from Wyoming State Geological Survey and the Water Resources Data System (2001). Contour lines are at 250 m intervals

Rockslides are considered the third most important type of landslide in the region in regards to volume of material moved (see Table 2.2) and these features seem to occur almost as frequently as earthflows (Merrill 1974:66). Figure 2.2 shows a wide distribution of rockslides across the area, indicated in grey. Activity from periglacial features such as rock glaciers are numerous in the upper cirques (Breckenridge 1974:86). Inactive and active rock glaciers are shown in light blue in Figure 2.2. Other types of landslides, such as mudflows, are scattered throughout the Greybull region (Merrill 1974:66). These other mass-wasting features are shown in yellow in Figure 2.2.

Due to the magnitude of mass-wasting features along the Absaroka Range, specific features have been the source of geological investigation. Pierce (1968:235) considers the mass-wasting complex along Carter Mountain (just north of the study area) as one of the largest landslide masses mapped. In a pedestrian survey of this area, Pierce (1968) notes the complex covers roughly 220 km^2 and was formed in two separate periods of movement indicated by differences in degree of erosion and by crosscutting relations. According to Pierce's (1968) observations, older earth-flows, mudflows, and slumps originally extended over the entire landslide complex area and that the younger landslides are mostly reactivated older ones. Breckenridge (1974) makes a similar assessment in the Wood River Drainage and suggests that while landslides in the past were larger, the presently active mass-movements, while mainly small-scale, collectively exceed the extent of old slides. Younger features have sharper topography and, along the Carter Mountain complex, younger landslide deposits contain 95% of the lakes and ponds. The formation of these sag ponds, which are also mentioned by Merrill (1974:65), have proved important to this study and archaeological preservation in the region, creating areas for sediment accumulation. Site 48PA2811 lies within a large multiple slump/flow mass which contains sag ponds (see Figure 2.2).

The factors resulting in the high occurrence of surface processes in the study area are many. Pierce (1968) sees the activity on Carter Mountain as due in large part to the instability of the Willwood Formation coupled with the weight of the overlying volcanic rocks. Others (Breckenridge 1974; Merrill 1974) also include bedrock as a primary factor in slope failure but identify the high relief, steep slopes accentuated by glaciation, high snowfall, and high earthquake frequency of the region as additional factors. Climate, particular the infiltration of water, is reasoned to instigate failure in slopes (Pierce 1968). Increased precipitation related to glacial-pluvial activity is underscored by Breckenridge (1974) as an important factor in past landscape instability along the Wood River valley.

Continued landscape instability is likely, though movement is predicted to be at a much more localized scale. Pierce (1968:239) and Breckenridge (1974) note that while the bulk of both old and young landslide features appear to be stable, local areas of active landsliding occur on both the younger and older landslide surfaces. The complexity of local processes will be illustrated in Chapter 4.

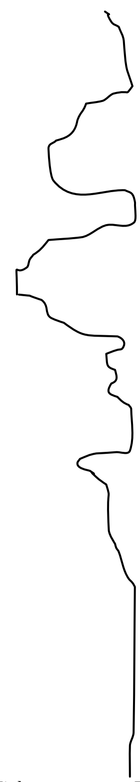
Climate Change and Biotic Responses

While bedrock geology is one factor contributing to the high amount of surface geological activity in Upper Greybull, climate and vegetation fluctuations also influence landscape stability and instability. Warming and drying trends, for example, can lead to drought and increased fires which in turn can result in increased erosion and episodes of mass-wasting (Meyer et al. 1992, 1995). This section begins with an introduction to global-scale climate change (change at a time scale of 10^5 to 10^4 years). Finer-grained environmental data from the Holocene are included to address environmental change at a 10^3 and 10^2 year timescale. There are no detailed paleoenvironmental studies specific to the Upper Greybull so to bracket the study region, vegetation change records from the Big Horn Basin are compared with environmental studies from the GYE. Studies that investigate the relationship between sedimentation, vegetation, and climate are introduced. Table 2.3 lists the regional climatic indicators that will be discussed.

Pleistocene

Global climate fluctuations have left an imprint in the landscape in the GYE and the Upper Greybull study area. During the Pleistocene an ice cap of about one kilometer in thickness covered the Yellowstone Plateau and flowed outward down major valleys that drain Yellowstone (Pierce 1979). This icecap was fed by glaciers from surrounding mountains, including the Absaroka Range. The immense size of the ice cap allowed it to influence weather and temperature patterns in the region (Pierce 1979). Alternating periods of glaciation and glacial floods shaped channel patterns and altered the landscape leaving U-shaped valleys, outwash fans, and moraines. Differing lithologies created by some of these features support specific vegetation communities such as the grasses and shrublands present on moraine deposits in the GYE (Despain 1990). Warming that occurred during the end of the Pleistocene marks the end of the Yellowstone ice cap and the Pinedale glaciation. Cosmogenic ages on outlet glaciers in northern Yellowstone range from 15.7+/- .5 ^{10}Be ka to 16.5 +/-.4 ^{3}He ka (Licciardi et al. 2001).

Table 2.3 Examples of regional climate indicators.
Glacial periods from Breckenridge (1974) and Dahms 2002. Five stages of vegetation change from Whitlock (1993). Colonization of *J. osteosperma* from Lyford et al. (2003) and Jackson et al. (2002). Fire and sedimentation data from Meyer et al. (1995). Cave mammals of Yellowstone from Hadly (1996).

Years BP	Glacial Periods Rocky Mountains	Yellowstone Vegetation phases	Colonization of *J. osteosperma*	Probable Fire-related Sedimentation	Lamar Cave mammals Frequency
0					*Microtus sp.,T. talpoides*
	Gannett Peak				in high abundance
500	Neoglaciation				*S. armatus* peaks
					S. armatus in high
1,000					Abundance
					Microtus sp.,T. talpoides
1,500					in high abundance
2,000			*J. osteosperma*		
3,000	Temple Lake				
	Neoglaciation		*J. osteosperma*		
4,000			Absent		
		5. *Pinus, Picea,*			
5,000		*Abies* forest			
			J. osteosperma		
6,000	Interglacial				
		4. *Pinus contorta*			
7,000		forest with			
		Pseudotsuga			
8,000			Migration of		
			J.osteosperma		
9,000			Utah/Wyoming	High Low	
			Border		
10,000		3. *Picea-Abies-Pinus*			
		albicualis forest			
11,000					
	Pinedale glaciation	2. *Picea* parkland			
12,000			*J. osteosperma*		
		1. Alpine meadow	Absent		
24,000		and shrubland			
	Interglacial				
36,000					
48,000					
	Bull Lake glaciation				
125,000					

The preservation of glacial landforms in the Upper Greybull is not particularly good because of the erosive Absaroka volcanics, but Breckenridge (1974) finds evidence along the Wood River to refine the local glacial chronology. The region contains remnants of two Wisconsin age tills which are assigned to the Bull Lake and Pinedale glaciations (Breckenridge 1974). The eastern slope of the Absarokas has not produced absolute dates for these periods and there is no doubt variation in these chronologies. A general age for these glaciations is listed in Table 2.3.

Pleistocene/Holocene Transition

Localized impacts of climate change during the Pleistocene/Holocene transition are evidenced in changes in vegetation reflected in pollen records from lake cores in and around Yellowstone Park. The Pleistocene/Holocene transition shows a gradual transition from the alpine meadow and shrub community of ice age times to the establishment of a subalpine forest similar to the present-day spruce-fir-whitebark pine (*Picea-Abies-Pinus albicaulis*) forest. Table 2.3 lists these vegetation shifts.

Whitlock's (1993) research indicates that conifer community response to Holocene climatic perturbations is varied. Phase four corresponds with an interglacial period and is characterized by an increase in diploxylon pollen, attributed largely to lodgepole pine *(Pinus contorta*), the dominant conifer of the region today. This reflects the early Holocene (9000 to 6000 yr BP) drying trend in central and southern Yellowstone. Due to orographic influences, northern Yellowstone actually became wetter in response to enhanced monsoonal circulation during this time period (Whitlock and Bartlein 1993). The Upper Greybull reflects a relatively summer-dry regime and, under the orographic model, conditions would have been drier during the early Holocene.

Breckenridge (1974) attributes intense down-cutting of streams in the Wood River to the Altithermal period (Antevs 1955), a warming trend during the early-to-mid Holocene.

Vegetation shifts in the Wind River Canyon and Big Horn Basin, in the form of the colonization of Utah juniper (*Juniperus osteosperma*), suggest drier periods during the Holocene (Jackson et al. 2002, Lyford et al. 2003). During the last glacial period, lowlands in northeastern Utah, central Wyoming, and southern Montana harbored higher-elevation vegetation such as limber pine (*Pinus flexilis*), blue spruce (*Picea pungens*), Douglas-fir (*Pseudotsuga menziesii*), and Common juniper (*Juniperus communis*) (Lyford et al. 2003:568). The spreading of *J. osteosperma* corresponds with the early Holocene (see Table 2.3), colonizing near the Utah/Wyoming border (ca 5400 yr BP) (Lyford et al. 2003: 578).

Middle and late Holocene

In addition to major glacial periods during the Wisconsin, there is evidence that high mountain cirques in the region remained glacially active during the Holocene. This Neoglacial period includes two to three glacial advances in the Absarokas. Breckenridge (1974) correlates the early and late advances of the Neoglacial with the Temple Lake and the Gannett Peak stadia (see Table 2.3), two previously identified advances in other mountain regions (Dahms 2002; Richmond 1960). The Temple Lake advance is represented in the Wood River by a massive moraine 61 m in height below Dollar Mountain (Breckenridge 1974: 66, see also Reitze 2004). To understand the local impact of these Neoglacial events, Breckenridge (1974) computes past orographic snowlines, or the lower limits of a perennial snowfield, for the region using a method by Richmond (1960). This method averages Pleistocene snowlines as the median altitude between the terminal moraine and cirque headwall for individual glaciations. Based on this method, snowlines for the Bull Lake, Pinedale, and Neoglacial were at 2,958, 3,050, and 3,141 masl in the upper Wood River Basin compared to a present orographic snowline of 3,660 meters (Breckenridge 1974:26). Snowline fluctuations during the Neoglacial no doubt had a local effect on animal movements, vegetation, and people.

Middle and late Holocene variations are not included in the Whitlock's five phases on vegetation. The final phase indicates an increase of *Pinus* percentages and a decrease of *Pseudotsuga* values around 5,000 years ago. Whitlock (1993:189) notes however that in the last 1,000-2,000 years vegetation has become more park-like and this may be the result of climatic conditions (warming trends), more frequent fires, and an increase in bark-beetle infestations arising from both.

The colonization of *Juniperus osteosperma* is more episodic in the Bighorn Basin and northern Wind River Basin during the middle and late Holocene and appears to be directly related to local moisture availability. A cessation at 5,400 years ago corresponds with a transition to relatively wet climatic conditions. Colonization continues again between 2800-1000 yr BP (Lyford et al. 2003:578). In the Wind River Canyon, *Juniperus osteosperma* is absent from all middens during a wet period from 3900-2800 yr BP, but evidence of its colonization occurs in this area during a dry period between 2100-1900 yr BP (Jackson et al. 2002).

Additional fine-grained paleoclimate proxies in northeastern Yellowstone National Park correlate post-fire sedimentation to warm, drought-prone periods in the middle to late Holocene (Meyer et al. 1995). Table 2.3 lists the probability of fire-induced sedimentation through time and is based on identified fire-related debris flows as well as possible and probable fire-related sedimentation. Fire-related deposits make up approximately 30% of the late Holocene fan alluvium. Fifty radiocarbon ages on fire-related depositional events indicate clustering of events at particular time periods. One such cluster or pulse in fire-related debris flow frequency corresponds with the colonization of *Juniperus osteosperma* in the Wind River Canyon around 2,000 years ago. Another major pulse occurs between 950 and 800 yr BP. This later pulse coincides with the Medieval Climatic Anomaly (or Medieval Warm Period). In between periods of frequent fire-related debris flows, Meyer et al. (1995) record periods of lateral migration and broadening of floodplains. These periods coincide with the ~1400-year Holocene cycle of cold episodes in the North Atlantic (Bond et al. 1997). Interestingly, the Altithermal period does not register at all in the records provided by Meyer et al. (1993, 1995). This is likely due to the orographic influence in this region of the Greater Yellowstone Ecosystem.

A final fine-grained proxy is displayed in Table 2.3 in the form of small mammal species at the Lamar Cave site in Yellowstone National Park. These animals provide a more sensitive indicator of late-Holocene ecological response to climatic change (Hadly 1996). In general, vole (*Microtus sp*.) and pocket gopher (*Thomomys talpoides*) are both considered mesic indicators. Hadly (1996) points out that increased frequency of these animals corresponds with the cooler, wetter conditions of the Little Ice Age (700 to 100 yr BP). Uinta ground squirrel (*Spermophilus armatus*) is found in more xeric microhabitats where cover is sparse and visibility unrestricted. The abundance of this particular fauna corresponds with the more xeric conditions during the Medieval Climatic

Anomaly (circa 1000 to 650 yr BP) (Hadly 1996:308). This also corresponds with the record put forth by Meyer et al. (1995).

The set of environmental proxies in Table 2.3 shows different scales of environmental change that have occurred in the Greater Yellowstone Ecosystem and in adjacent regions. While these different paleoenvironmental indicators are not perfectly correlated, it appears global-scale climatic fluctuations influence local processes. This relationship is not strictly limited to the last major ice age but extends into the Late Holocene and at this scale landscape change is very dynamic and interconnected.

Animal and human populations are no doubt influenced by fluctuations in vegetation and climate. Wolves, bison and elk were present in the GYE region some 9,000 years ago, though population size and distribution through history is unknown and up for speculation (Cannon and Cannon 2004). Frison (1991) identifies bison remains in high elevations of the Absarokas. The remains of a bison forelimb were identified in 2004 at 48PA2811 and are now known to post-date 950 RCBP. A bison horn sheath was also found in a cirque basin of the Upper Greybull study area at 3,330 masl. Zooarchaeological evidence of bighorn sheep goes back at least 10,890 RCBP in the Absaroka Mountains (Hughes 2003; Husted and Edgar 2002).

People

Mountain ecosystems, as illustrated above, are dynamic and diverse landscapes. The archaeological record indicates that the Rocky Mountain region was used for a variety of purposes over a long period of time (Bender and Wright 1988; Frison 1991; Husted and Edgar 2002). Bender and Wright (1988:626) propose that prehistoric hunters and gatherers seasonally scheduled occupations of mountainous areas in order to procure a wide variety of resources available there, taking advantage of elevation differences opening different areas for resource allocation throughout the year. Benedict (1992) lists several factors, such as distance to water, quality toolstone locations, and grazing areas for large game, to name a few, that influence human movement and occupations in the Colorado Rocky Mountains. The influence of local factors on resource distribution and the lack of archaeological data in many mountainous enclaves, makes developing a general regional cultural chronology difficult. The following is a brief overview of archaeology near the Upper Greybull River in the context of the northern Great Plains region.

Geographically, the Absaroka Range and the surrounding ranges of the Middle Rocky Mountains create an ecological island on the North American Great Plains (Kornfeld and Osborn 2003) as well as make a shared niche from different groups of people through history. The Absaroka Range is often adopted in northern Plains archaeological discussions and is given the prehistoric time periods of this region. These time periods, generally based on technological shifts in projectile point type are the Paleoindian (11,500 to 8000 RCBP), Early Archaic (8000 to 5000 RCBP), Middle Archaic (5000 to 3200 RCBP), Late Archaic (3200 to 1500 RCBP), and the Late Prehistoric (1500 to 250 RCBP). Chronologies are in part out of convenience and do not indicate extreme shifts in lifeways.

The first evidence for human occupation in the northern Plains occurs during the Paleoindian period. Single component sites throughout the region are associated with small band nomadism and a focus on the migration of large prey species (Frison 1991).

The principle species used was *Bison* spp., but the first evidence of the exploitation of large prey species is associated with mammoth (Frison and Todd 1986). Evidence from the foothill and mountain areas around the Big Horn Basin of the northern Plains indicates a broad spectrum hunting and gathering tradition, otherwise referred to as the Plains Foothills-Mountain tradition (Frison 1991, 1992, 1997; Husted 1969). Archaeological evidence from the Absaroka Range is included in this tradition. The true breadth of plant and animal resources used in this tradition is not known, but groups who inhabited foothill-mountain regions were reliant on upland resources, notably mountain sheep.

There are a few sites in the Absaroka region that contain dateable Paleoindian materials. Most notable is the Mummy Cave site to the north of the Upper Greybull study area along the North Fork of the Shoshone River. The archaeological record of Mummy Cave shows continued occupations beginning at about 10,000 years ago to historic times (Hughes 2003; Husted and Edgar 2002; Wedel et al. 1968). Mountain sheep were most heavily used through the history of occupation at this site. A large animal trapping suitable for hunting animals the size of deer and mountain sheep, was discovered in a cave on Sheep Mountain in the Absaroka Range and dates to the Late Paleoindian (Frison et al. 1986). The Helen Lookingbill site is another stratified, high elevation site also located in the Absaroka Mountains with the earliest evidence of occupation dating to 10,400 RCBP and with additional occupations following (Kornfeld et al. 2001).

The Early Archaic marks a shift in projectile point technology from lanceolate and stemmed projectile points to side-notched projectile points (Frison 1991). A lack of archaeological occupations during this time has been attributed to drier Altithermal conditions and a subsequent abandonment of the Great Plains. Mountain ecosystems have been considered refugium for human populations in this time of environmental stress, but these generalities are scrutinized (Bender and Wright 1988). Evidence indicates that people continued to use the basins and plains throughout the Early Archaic (Frison 1991; Reeves 1973), and in the Upper Greybull, projectile points associated with the Early Archaic period are rare (Burnett 2005). Increased erosion and deflation are also considered factors in a region-wide lack of sites during this period (Albanese and Frison 1995; Ferring 1995; Mandel 1995).

Certain features of the Early Archaic can be identified. Subsistence strategies suggest a gradual shift of focus to smaller scale resources at a more local level through time indicated in part by increased investment in structures (i.e., pit houses) (Frison 1991; Larson and Francis 1997) and an increase in plant processing. Pit houses in mountain areas dating to this time period have not been discovered. Early Archaic strata at the high elevation site of Helen Lookingbill contains a deer bone bed dating between 6500 and 6800 RCBP as well as manos and grinding stones (Frison 1983; Kornfeld et al. 2001).

Grinding stones and food preparation pits proliferate in the record during the Middle Archaic period in the northern Plains (Frison 1991). The Middle Archaic period is commonly associated with the widespread McKean technological group (Frison 1991). A Middle Archaic occupation at the Dead Indian Creek site of the Absaroka Mountains containing a pithouse structure was used as a winter camp for several months while people utilized deer and mountain sheep (Frison and Walker 1984). Numerous manos and metates were recovered as well. Mummy Cave displays a diversity of artifacts associated with the McKean period including; cordage, basketry, wood and bone artifacts (Husted and Edgar 2002, Wedel et al. 1968). Grinding stones associated with this period were found at Mummy Cave but not to the extent of other locations throughout the Great Plains (Wedel et al. 1968).

Archaeological evidence across the northern Plains is most prevalent during the Late Archaic period. The Upper Greybull reflects this general pattern based on the dominance of projectile points cross-dated to this period (Burnett 2005). Land use appears to have more than doubled during the Late Archaic. Diverse subsistence strategies are typical of this period, however; Mummy Cave shows little evidence in the way of plant processing. In a comparison with the Foothill-Mountain Bighorn data and sites in the Absaroka Range, subsistence strategies in the Absarokas were likely more hunting focused than in prior periods based on the lack of lithic plant processing tools (Burnett 2005:44).

Maximal use of mountain landscapes in the Middle Rocky Mountains continues into the Late Prehistoric period. The Late Prehistoric marks the transition from dart points to smaller bow and arrow point technology. The Bugas-Holding site in the Sunlight Basin of the Absarokas, just north of the Upper Greybull, contains evidence of winter use of the Absarokas based on bison and mountain sheep dentition (Rapson 1990). Late Prehistoric occupations at Mummy Cave are associated with the Shoshonean occupation of mountainous areas in the region based on specific projectile point style (Husted and Edgar 2002). Pottery makes an appearance in the northern Plains at the end of the Late Archaic and continues into the Late Prehistoric. Pottery fragments were found only at the uppermost levels in Mummy Cave, 20-30 cm below surface (Wedel et al. 1968)

A contact period between Europeans and Native populations before European settlers were established called the Protohistoric period follows the Late Prehistoric. This was a fluid and dynamic period with the introduction of trade goods and cultural interaction. Occupations associated with this period, based on the presence of glass trade beads, have now been documented in the Upper Greybull. Paramount to this period was the acquisition of the horse by tribes in the GYE region, though some Shoshonean groups, referred to as the Sheepeaters, did not obtain horses (Frison 1991; Janetski 2002; Whitley 2000).

Archaeological evidence for historic mountain occupations exists in the Upper Greybull. Ranching has a long history in the area as evidenced by historic cow camps and sheepherder camps. This livelihood goes back to the late 1800s in the Absarokas. Mining in the Upper Greybull was not a lucrative venture as Mueller (2007) points out, though the Wood River Drainage contains many residuals of the boom days when the town of Kirwin was established.

Landscape Change and Archaeology

The archaeological record in mountain regions, including the GYE and Upper Greybull is by no means complete. Yellowstone National Park has been considered one of the poorest archaeologically known areas in North America (Wright 1982). Certainly the nature of the landscape and its evolution influence the cultural record. The ephemeral nature of human residence, as shown by the archaeological record, is linked to the ecological variability of the GYE and Upper Greybull area. Temperate environments with pronounced seasonality have a discontinuous distribution of critical resources (Benedict 1992; Binford 1980; Kelly 1995). Hunter and gatherer settlements in these environments are composed of a variety of specialized site types, most of which are not high-profile (Binford 1980). An understanding of landscape change is necessary.

Surficial processes have a key role in archaeological interpretation and preservation. Large occupation sites in the northern Plains are located on floodplains and stream confluences (Reeves 1973). These land surfaces are prone to multiple landscape processes. As mentioned before, evidence for large-scale sedimentation and erosion across the Great Plains during the middle Holocene is believed to have resulted in the burial and destruction of archaeological materials (Ferring 1995; Mandel 1995). These disturbance regimes are also identified in intermountain areas of the northern Plains (Albanese and Frison 1995). Cycles of erosion and deposition in the GYE have continued into the late Holocene with increased frequency (Meyer et al. 1993, 1995). Even at a small time scale mountain environments a subject to landscape change. Benedict (1970) provides evidence along the Colorado Front Range of down slope soil movement rates of .4 to 4.3 cm/yr.

Based on the geological past of the Upper Greybull and its present surface geology, disturbance patterns define the landscape, but these landscape features are seldom combined with the archaeology. Figure 2.3 is a map of the Piney Creek drainage. The arrow indicates site 48PA2811. Both the surface geology and identified archaeological sites are mapped in this figure. Multiple landslide features mark the landscape and a number of archaeological sites are located within these features. Sites indicate occupation along this drainage since the Late Archaic. These occupations suggest surface stability since this period, but it is uncertain if these landslide events have erased older occupations. It is also uncertain the ecological changes and changes in resource distribution that may have followed these disturbance regimes.

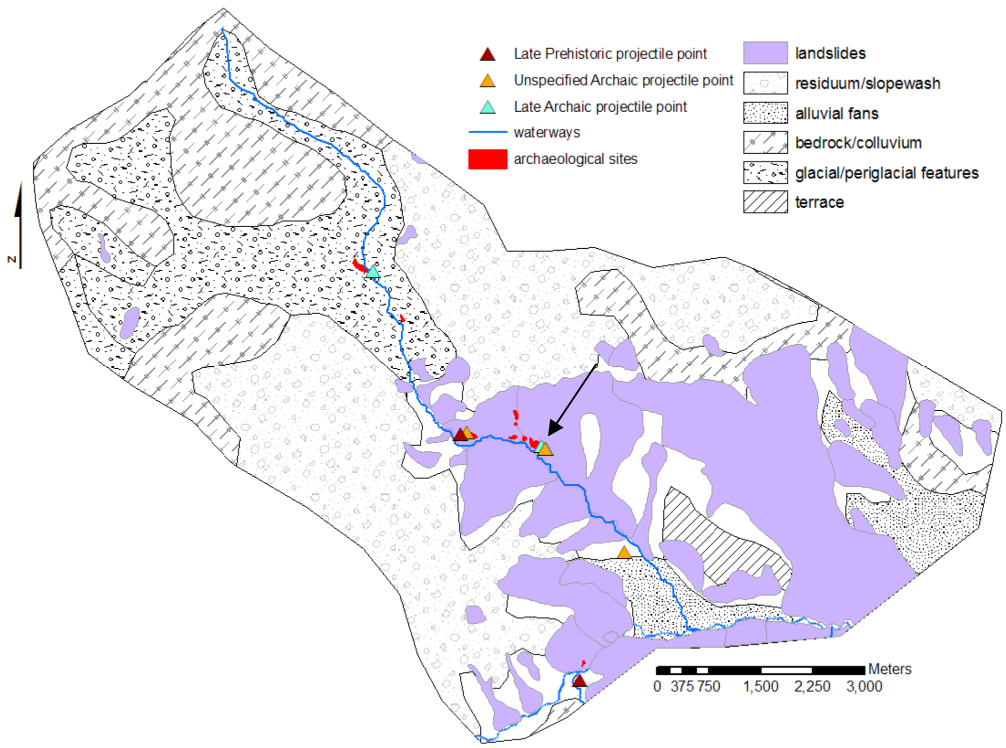


Figure 2.3 Upper Greybull, Piney Creek landscape.
Landslide data from Wyoming State Geological Survey and the Water Resources Data System (2001), surface geology data from Case et al. (1998).

While Figure 2.3 demonstrates a relationship between landforms and archaeological sites, these relationships cannot be fully understood at this spatial scale. An in-depth look at site 48PA2811 will answer questions regarding the relationship between archaeological record and landscape change and especially how large-scale processes influence site-specific processes.

The purpose of this chapter was to show the dynamics of landscape change in the Upper Greybull at different scales, from deep geological time to the human time scale.

An additional intent of this discussion was to illustrate, by examples, that there is no fine line between changes in one particular sphere, such as climate, and another sphere, like geology or biology. At the end of the chapter, I focused in on changes in the Piney Creek drainage. The Piney Creek drainage has whitnessed multiple transformations through time, but the tempo of these changes is uncertain, the impact of the archaeology is unknown, and the impact of geologic change on other components of the landscape can only be speculated from the spatial data.

The following chapter explains the methods used to quantify and qualify landscape change at a regional scale across the Upper Greybull. The methods used at archaeological site 48PA2811 are also explained. Due to the constraints of this thesis, site 48PA2811, receives more attention. Subsurface and micro-scale investigations are used at this site location to understand these larger-scale processes. Soil formation, in particular, can reflect multiple factors in landscape condition and microenvironmental changes. The combination of theory, already discussed, and methods, discussed in the following chapter, will be the backbone in creating a story of landscape change.

CHAPTER 3: METHODS

A variety of methods are applicable to the study of landscape evolution. The choice in methods and number of methods used is of course limited by available data, available time, available money, and the investigator's intellectual toolbox. Figure 3.1 is a breakdown of the organization of the methods. Methods encompass two scales of observation: a study area-scale of the Upper Greybull and the archaeology site-scale. Method type is archaeological and natural science based, though there is a continuum. For instance, archaeological survey in the Upper Greybull must take into account land surfaces and deposition. A brief discussion of survey and artifact documentation is explained below. This thesis does not focus on artifact analysis—only the methods involving site documentation are included for this discussion. GIS methods to identify landslides and archaeological associations are further explained. Site-scale methods take the form primarily of stratigraphy and soil analysis. Soil laboratory methods are specifically outlined. All radiocarbon dates were produced by BETA analytic and these methods are also provided.

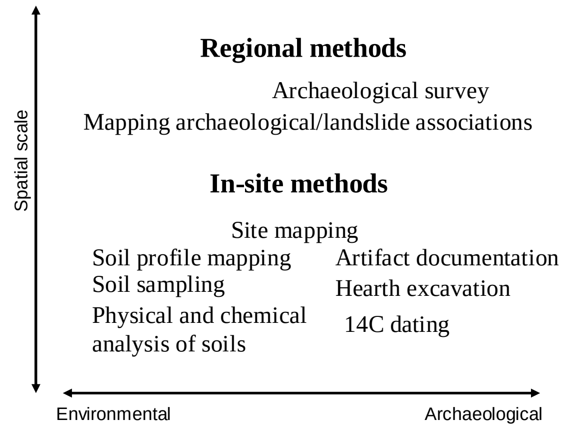


Figure 3.1 A categorization of methods based on spatial scale (Y-axis) and emphasis (X-axis).

Regional Scale Methods

Archaeological discovery in the Upper Greybull River study area begins with pedestrian survey, either formal (walking transect lines) or informal (‘noodling’). Sampled areas for survey include the narrow floodplains and terraces of the Greybull River and its many tributaries, softly rolling uplands, and glacial cirques. Areas with subtle topographic variation are usual targets for survey however some steep hillsides are noted to contain rock structures (for discussion see Kinneer 2007). Large expanses of land, for example 10 hectares, are commonly scanned by field a crew of between 7 to 17 people at 5 meter transects. ‘Noodling’ occurs in areas where a site has been located but the spatial extent of the site is not yet known and in smaller topographically confined areas such as a remnant terrace or alluvial fan. Crawling surveys with a field crew spaced at 30 cm apart are ideal where high concentrations of artifacts exist.

Artifact documentation is non-collection, in other words, all data gathering occurs in-field. Individual artifacts characteristics are recorded on iPAQs (handheld computers) and documented based on a variety of artifact characteristics listed in Appendix A. In some cases, due to time constraint and field crew members, the list of characteristics recorded in the field is simplified (see Burnett 2005 for discussion). In addition to documenting these characteristics, UTM coordinates for each artifact are marked by GPS units at an accuracy better than 8 meters and in some cases an EDM and sub meter GPS units are used. The coordinates of these artifacts and their attributes can then be plotted in a variety of mapping programs.

Spatial analysis for this study used GIS (geographical information systems) to identify associations between mass-wasting events and human occupation. A landslide database created by the Wyoming State Geological Survey and the Water Resources Data System (2001) is used in association with data from archaeological surveys from 2002-2006. The landslide or mass-wasting map was created based on aerial photographs. The spatial database has an accuracy of 40 meters. Site polygons, drawn in the field using the track log option on a Garmin GPS, are plotted with landslide polygons. The 'clip' tool, or cookie-cutter function, in ArcGIS is used to determine any overlap with archaeological sites and mass-wasting features. The number of associations and type of associations are identified.

Cross-dating of surface archaeological components by means of regional projectile point chronologies is used to look for a relationship between the landscape surface and the time of human occupation. Projectile point type is often identified in the field and type is attributed to an archaeological period (for an extensive discussion on cross-dating in the Upper Greybull see Burnett 2005). Projectile points that fall into a particular period are plotted on a map that includes landslide polygons, and ArcGIS software is used to match mass-wasting surfaces commonly associated with specific projectile points.

IN-SITE METHODS

Archaeological Documentation and Excavation

At the archaeological site-scale cultural items on the surface are documented using the same standards as described above. A noodling survey was performed in 2004 at site 48PA2811. In 2005 a formal survey using a modified Whittaker sampling plot was performed (Burger 2002; Burger et al. 2004). The results from each survey are contrasted using ArcGIS software.

Subsurface cultural components were treated differently than surface artifacts at 48PA2811 due to the highly erosive behavior of the Piney Creek cutbank. A hearth feature was excavated from this bank on June 1, 2005 before further destruction of this feature by natural processes (Figure 3.2). As the hearth fill was excavated, all sediment, charcoal, and hearth stone samples were removed and labeled. With the exception of the hearth stones, which were weighed and left in the field, all hearth fill was returned to Colorado State University for processing. Appendix B lists all collected samples gathered and their locations. Hearth samples not used in the following analyses are stored at the Laboratory for Human Paleoecology at Colorado State University. Wood still preserved in the hearth was collected, identified, and used for radiocarbon dating.

Figure 3.2 Photograph of excavation of hearth feature.

Charcoal samples from the excavated hearth were selected for identification as well as a few select pieces of charcoal from one of the buried soil horizons. Identifying species of wood was based on observation of specific characteristics of the wood through a microscope. These characteristics include the distribution and size of resin canals, ray size, and grain size. Charcoal samples were cleanly snapped apart along the transverse plane of the wood for an unaltered view of the wood's character. A microscope in the laboratory for plant disease in the Plant Sciences building at Colorado State University was used. Forestry professor Kurt Mackes and graduate student Mike Eckhoff supervised the identification.

Profile Mapping, Soil Sampling, and Dating Methods

The stratigraphy, soil development, and cultural layers contained in the creek bank profile were mapped to document variations in soil development, deposition over time, and cultural associations. Mapping of the exposure involved two-three people and took place between May 28 and June 1, 2005 returning again July 11-13, 2005 to finish. A level line was run through the middle of the profile and given the arbitrary elevation of 100 meters. From the level line, changes in stratigraphic units, bioturbation, and cultural features were mapped. One to two people took measurements throughout the length of the profile of where changes in stratigraphic units occurred. Changes were documented at every 10 cm horizontal interval along the span of the level line. One person plotted these measurements and mapped in changes. Charcoal and sediment samples were plotted on the map and coordinates were shot with an EDM. A profile map of 18 m long and 2.5 m wide was constructed (field illustrations are shown in Appendix B).

Soil samples were acquired from the stratigraphic units of the profile for laboratory soil analysis. Initial soil sampling took place June 2, 2005. These samples were not gathered in even intervals due to the erosion of the cut bank, rodent disturbance, and also the frozen nature of the soil at the time of gathering. Each location of soil sampling was plotted on the profile map and also shot with an EDM using UTM coordinates (WGS84) derived from differentially connected static GPS network survey. Additional soil samples were taken in September 2006 to rectify sampling. These additional samples were gathered in two sections of the profile in soil-forming layers. This included sampling the modern A horizon and taking samples above, below and within the three buried soils. All samples were extracted by a trowel and put into sediment bags or Ziploc bags with limited handling. Samples not used in following analyses are located at the Laboratory for Human Paleoecology, Colorado State University. Field notes on texture, structure, and inclusions were recorded. Field data regarding soil sampling are in Appendix C. Soil color was described in the laboratory.

Radiocarbon dating

Dates from the buried hearth feature (Feature 1) and from buried soils were produced by the carbon-14 (C14) radiometric technique. Samples were processed by Beta Analytic (BETA). Charcoal and partially burnt wood samples were gathered from Feature 1. Three samples were dated from the hearth to best confine the time period in which the hearth was constructed and used. Heart wood and the outer growth layers from the same log were both dated to bracket the lifespan of the tree (Beta-206176 and Beta-206177). An additional date from the outer growth layers of another log was also produced (Beta-206178).

Four samples from buried soil horizons were also dated. These include two samples from the upper most paleosol in the profile (Beta-222040 and Beta-222042) and two samples from the bottom most paleosol (Beta-222039 and Beta-222041). A minimum of two samples was taken per layer to decrease the standard deviation. Radiocarbon dates from the soils were based on charcoal present in the soil layers, likely from remains of burned vegetation. Dating of soils is somewhat problematic, but ages from organic matter in buried soil horizons provide minimum ages of stability and soil formation and also maximum ages for subsequent deposition of overlying deposits.

Each charcoal sample received “acid/alkali/acid” pretreatment (in Pretreatment Glossary for Beta Analytic). Each sample was gently crushed and dispersed in deionized water. Any carbonates present were removed by repeated hot acid (HCl) washes. Secondary organic acids were removed by alkali washes (NaOH). Beta Analytic Inc. took each sample through serial rinses based on qualities of each sample. Rootlets and associated sediments were eliminated in the process.

Descriptive and Quantitative Soil Methods

Soil preparation took place in the Soil Geochemistry and Pedology Laboratory of Dr. Gene Kelly and PhD candidate Suellen Melzer in the Plant Sciences building at Colorado State University. Field samples from soil-forming layers and depositional layers went through the same analyses. All samples were air-dried, lightly pounded with a rubber mallet to break up conglomerates, and then sifted through a 2 mm sieve to separate roots and larger clasts to prepare for analyses. Roots were discarded and larger clasts from depositional layers were kept as geologic samples. Soils and sediments were stored temporarily in 4 oz plastic containers. Samples were given a color, both wet and dry based on the Munsell soil color chart (Munsell 1975) in the laboratory.

Particle size

The variation in particle size can be due to inheritance from the parent material, mechanical weathering, and atmospheric additions of solids to the soil (Birkeland 1999:10). Soil texture is used in this study to understand the energy of deposition (geomorphic) to produce the creek bank stratigraphy and to identify properties in soil forming layers (pedogenic). The hydrometer method, adapted from Bouyoucos (1936) was used to find class sizes of sand, ranging from 2-0.050 mm; silt, ranging from 0.050-0.002 mm; and clay <0.002 mm.

Approximately 50 grams (in a few cases 30-25 grams were used due to limited supply of specific samples) of each soil were measured by a Mettler AE166 scale. Nalgene bottles (size 250 ml for 50 grams of soil and 125 ml for 30-25 grams of soil) complete with screw-on lids and labeled with a laboratory sample number were weighed before each sample was added. A salt solution (Calgon Bath Salt), containing the key ingredient sodium hexametaphosphate to breakup conglomerates, was created using fifty grams of Calgon to one liter de-ionized water. One hundred milliliters of this solution was added to each of the bottles containing the weighed soil samples. These mixtures were taken to the General Prep Laboratory in the Plant Sciences building and left to shake overnight for a minimum of 10 hours.

A control cylinder of 100 ml of salt solution and filled to one liter mark on a graduated cylinder with de-ionized water was created. Samples were removed from the shakers (usually three to four at a time while others were left to shake) and each sample was processed individually in the following steps.

The soil solution was added to a labeled 1000 ml cylinder and de-ionized water was added to fill to the one liter mark. Paraffin was applied to the top of the cylinder and the cylinder was shaken back and forth 10 times, completely inverting the cylinder. The cylinder was set down on the counter while a stop watch was set. At the 25 second mark the hydrometer was put in the solution and at 40 seconds a reading was recorded from the hydrometer. Paraffin was then reapplied and the sample was shaken a second time and left to settle for 40 seconds before both temperature and hydrometer were recorded once again. Finally, paraffin was applied to the top of the cylinder a third time and the cylinder was shaken in the same manner as before. The cylinder was set down on the counter while a stop watch was set. This time the cylinder was left for exactly two hours before a final hydrometer reading and temperature was taken. While a soil sample was settling for the last reading, additional samples could be processed for the 40 second readings. The control cylinder was recorded for temperature and hydrometer reading between each sample. Roughly eight samples could be run at a time with five stop watches keeping track of time.

Data gathered from particle size are available in the Appendix D. Equations for computing percentage clay, silt, and sand are included.

Soil pH

Soil pH is a factor of biota, climate, parent material, and time (Jenny 1941). Soil pH can hinder or promote organic preservation, which is important for archaeological preservation. The method for recording total pH is adapted from Janitzky (1986). A pH meter from Dr. Jim Ippolito's lab in the Plant Sciences building was used. Approximately 10 grams of soil were measured into individual (50 ml) beakers. While stirring, 10 ml of de-ionized water were added to each beaker to create a 1:1 ratio. The soil slurry then was put aside for 30 minutes. The pH meter was turned on and calibrated by placing the electrode in seven pH calibrated solution and then a 10 pH solution. After the calibration, the meter was inserted in each slurry sample after stirring the slurry. A beep would indicate a reading and the number was recorded. Both the electrode and stir-rod were rinsed with de-ionized water each time after placing it into a new solution.

Organic Carbon

Organic matter (OM) is generally most concentrated in the uppermost horizon and can be used to indicate organic horizons (A) in buried soils (Birkeland 1999). OM includes matter such as undecomposed plant and animal tissue and humus. Humus makes up the bulk of the soil organic matter (Schaetzl and Anderson 2005). The percentage of organic matter is approximately 1.724 times the percentage of organic carbon (Birkeland 1999:11). The following methods; total carbon and nitrogen percentages and inorganic carbon are used to derive organic carbon.

Total carbon and nitrogen

While total carbon and nitrogen amounts are found in part of identify organic carbon and OM in soils, C:N (carbon to nitrogen ratios) can be used as a rough measure of the amount of decomposition of the original organic material and the steady-state values are related to environmental conditions. For example, a ratio for the A horizon near 20 seems to separate forested soils (>20) from non-forested soils (<20) (Birkeland 1999:11).

Total carbon/nitrogen percentages were determined using a LECO 1000 CHN elemental analyzer in the Natural Resources Ecology Laboratory, Colorado State University. Additional preparation of samples for this analysis required pulverizing each sample using a mortar and pestle. Tiny roots, if present were removed during the preparation. Approximately 5 grams of each soil were powdered and stored in glass bottles.

The CHN Analyzer used is located in the Natural Resource Ecology Laboratory on CSU campus. The crucible was emptied by Colin Pinney, and the machine was ready to be loaded. To calibrate the machine four blanks were run, followed by four controls, one blank, and finally one control before the field samples were run. Approximately .2 grams of each soil were measured into a tiny foil square. The sides of the foil square were folded up and twisted into a tear-drop shaped pellet with the soil sample wrapped tightly inside. Samples were loaded into a numbered tray and the name of each sample was typed into a spreadsheet on the LECO computer. After every ten samples, a blank and control sample were run. As each sample was run, the amount of nitrogen and carbon were plotted in the table (see Appendix F for all soil results). No further calculations were required.

Inorganic Carbon

Percentage of inorganic carbon is necessary to distinguish organic carbon and is also used to find $CaCO^3$ in soils (12% of $CaCO^3$ is inorganic carbon). While, $CaCO^3$ is expected to be low in the study area due to the absence of limestone and other carbonate-containing parent materials, inorganic carbon can influence pH values. Inorganic carbon was found using a pressure transducer and voltage meter (for detailed description see Sherrod et al. 2002).

A pulverized soil sample is required for inorganic carbon analysis. This analysis was preformed in the Natural Resource Ecology Laboratory, Colorado State University. Control samples for calibration were prepared by measuring approximately 1 gram of soils containing .25%, .5%, 1%, 2%, 3%, and 5% of $CaCO^3$ into 20-mL Wheaton serum bottles. Approximately 1 gram of soil samples from the 48PA2811 profile were measured and placed into additional labeled bottles. These bottles served as the reaction vessel for the soils. A 2 ml vial containing a 2 ml concentration of HCL is inserted into each soil sample bottle. Each soil sample bottle is then capped with butyl rubber stoppers and aluminum tear-off seals and sealed using a hand-held crimper. After each sample was fit with a vile of HCL and properly capped, the bottles were shaken vigorously in order for the soil sample and HCL to make contact. The bottles were then left for two hours. After the two hour period, one at a time, each bottle cap was pierced with pierced with a hypodermic needle that was attached to a pressure transducer monitored by a digital voltmeter. A maximum reading was taken for each sample and recorded. Only one sample had to be run twice due to a broken seal.

The percentage of inorganic carbon was figured for control samples and a calibration curve was developed. These calculations and weight, lab number, voltage reading, and percentages of inorganic carbon are listed in Appendix E.

Carbon isotopes

Stable carbon isotope values in soils are shown to have environmental significance (Cerling et al. 1989). The stable carbon isotopic composition in soil organic matter is largely controlled by plant type (Kelly et al. 1998:61). Two large plant groups, C_3 and C_4, differ in their $^{13}C/^{12}C$ ratios, due to differences in photosynthetic pathways (Farquhar et al. 1989). All trees are share the C_3 photosynthetic pathway, while about 50% of grasses possess the C_4 photosynthetic pathway (Bender 1968), thus $^{13}C/^{12}C$ ratios are often been used to look for transitions between forest and grassland communities. Carbon isotope values have also been used to look at drought stress among C_3 dominated plant communities (Stevenson et al. 2005). Values are expressed using the δ notation in per mil (‰), as the deviation of the isotopic ratio of the sample from that of an arbitrary standard:

$$\delta^{13}C=[(R_{SAMPLE}-R_{STANDARD})/R_{STANDARD}]x1000$$

where $R_{SAMPLE}= {}^{13}C/^{12}C$ of the sample and $R_{STANDARD}= {}^{13}C/^{12}C$ of the standard.

Values for $\delta^{13}C$ in this study were measured using a CARLOGRBA NA1500 elemental analyzer (C.E. Elantech, Milan, Italy), coupled to a VG isochrom isotope ratio mass spectrometer (GV Instruments, Manchester, UK) located in the Natural Resource Ecology Laboratory, Colorado State University. Soils were pulverized before the analysis.

Due to the high range of total carbon content in the soils, each sample was measured according to percentage carbon (i.e., high carbon soils were measured in smaller quantities). Soil sample weights ranged from approximately seven to 25 mg. Dan Ruess prepared and loaded control samples. A control sample was run after every ten field samples to ensure the machine was reading values consistently. Each sample was wrapped in a silver foil cup, folded up and smashed into a small ball. Samples were loaded into a numbered tray and the name of each sample was typed into a spreadsheet on a corresponding computer. As each sample was run, a print out of $\delta^{13}C$ counts was produced (see Appendix F for all soil results).

All results from the methods outlined above will be discussed and specific results will be compared in the following chapter. Laboratory results are coupled with field observations to look at the relationships between site topography, stratigraphy and soil formation. Results from various laboratory analyses are compared to look at multiple proxies that suggest evidence, or the lack of evidence, for landscape change in the form of climate, biota, and depositional environments. Data are combined to explore the relationships between geomorphic processes and environmental change and the tempo of these changes based on archaeological evidence and radiocarbon dating at 48PA2811.

Larger regional landscape change is evaluated based on relationships between multiple archaeological sites and their associated land surfaces.

CHAPTER 4: RESULTS AND INTERPRETATIONS

This chapter begins with a discussion of the archaeology of site 48PA2811. The site's geographic location and the prominent features that surround the site are included in the discussion. A detailed analysis of the stratigraphy and soil forming layers of the site, in terms of physical and chemical properties, follows the introductory discussion. The results from 48PA2811 are combined to construct a landscape history for this archaeological site complete with specific phases of landscape change through time. One of the dominant features encompassing 48PA2811 is a large multiple slump/flow remnant, and to put the processes occurring at 48PA2811 into perspective, the chapter includes a synthesis of mass-wasting features across the Upper Greybull and the associations between these land masses and archaeological sites. Patterns in site location and occupation period are discussed in terms of regional landscape change. Issues in regional archaeological preservation are also discussed.

Archaeology of Site 48PA2811

The surface component of site 48PA2811 is in a flat basin feature, part of an extensive slump/flow landform. Within the site area, the dominate vegetation is *Artemisia tridentata* while *Picea engelmannii* surrounds the basin. More than 500 artifacts make up the surface component, these include several bifaces, a scraper, two Late Archaic projectile points, numerous worked flakes, and fire-cracked rock scatters.

The site was recorded in 2004 and again in 2005. The initial survey was nonsystematic while in 2005 a modified Whittaker plot was used. Differences in artifact density are likely due to sampling methods and GPS accuracy which can range from 2 m to 10 or more, though as accuracy decreases, readings are not recommended. Figure 4.1 is a general map of the site area and includes artifact provenience recorded for both 2004 and 2005.

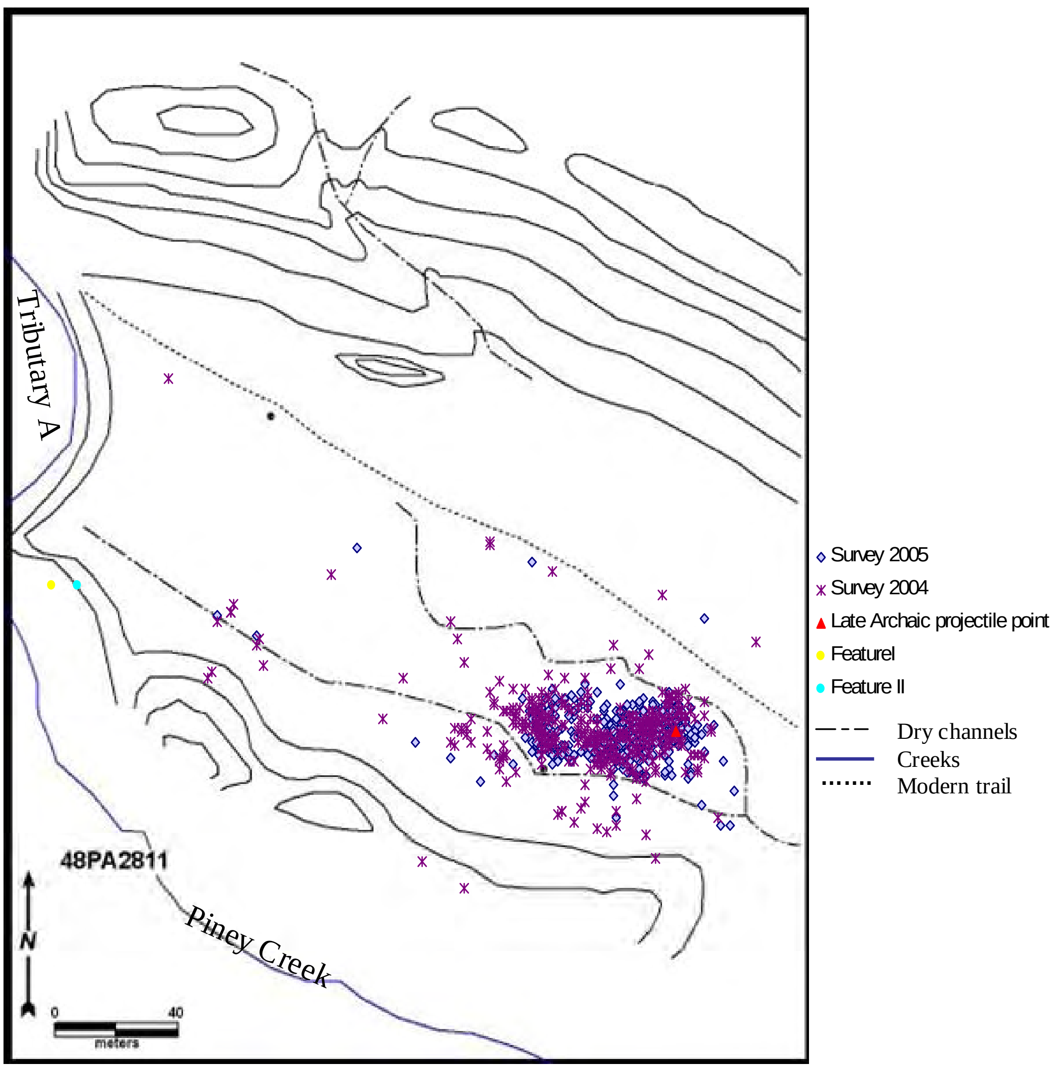


Figure 4.1 Archaeological site map of 48PA2811.
Contour intervals are at one meter.

Based on the location of the artifact concentration, shown in Figure 4.1, this concentration appears to be truncated by two dry channels that bisect the basin. These proposed remnant drainages are over a meter in depth. Snow accumulates in the channels leaving them vulnerable to seasonal runoff. These drainage features are also more susceptible to disturbances associated with fires. They were intensively burned in the wild fire of summer 2006. Modern disturbances from cattle, hunters, and recreationalists as well as natural disturbances of rodent burrowing, fires, and fire-induced erosion no doubt have an influence on the site's integrity, but the extent of this influence is not quantifiable at this time.

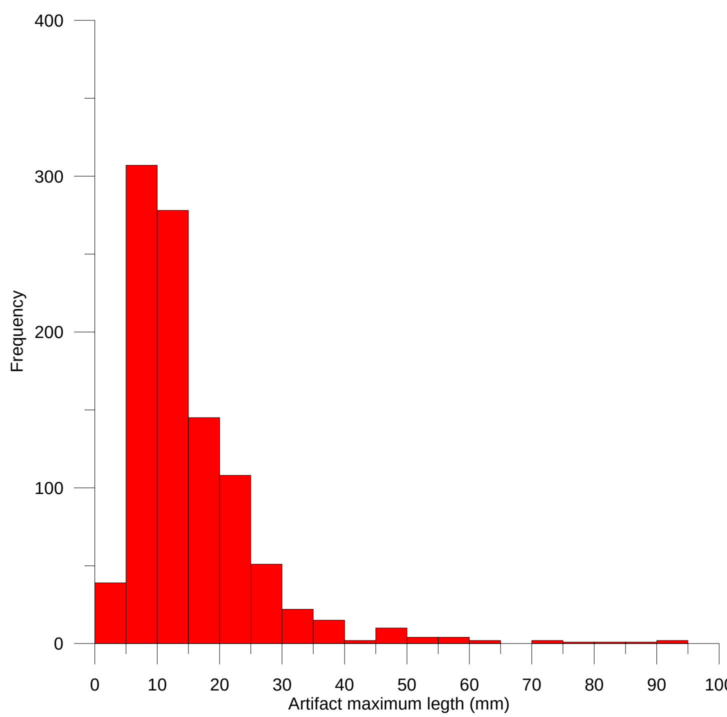


Figure 4.2 Frequency of artifacts based on maximum artifact length

There is an indication that the surface component of 48PA2811 has not been greatly disturbed based on the multitude of size ranges in artifacts at the site. Figure 4.2 is a histogram of showing the frequency of artifacts based on maximum length in millimeters from surveys in 2004 and 2005. The maximum length of artifacts ranges from 1.1 mm-115.0 mm and a high incident of flake sizes between 5-10 mm. This range in artifact size and the preservation of many small flakes indicates a degree of surface stability at the site.

An additional indicator of minimal disturbance in the surface component portion of 48PA2811 is the presence of a Late Archaic obsidian projectile point. This projectile point was located on the surface in 2004. An additional projectile point of similar style was located in 2006 after a wild fire cleared much of the vegetation. Both projectile points are pictured in Figure 4.3. A projectile point tip was also documented but does not contain characteristics diagnostic of a specific archaeological period.

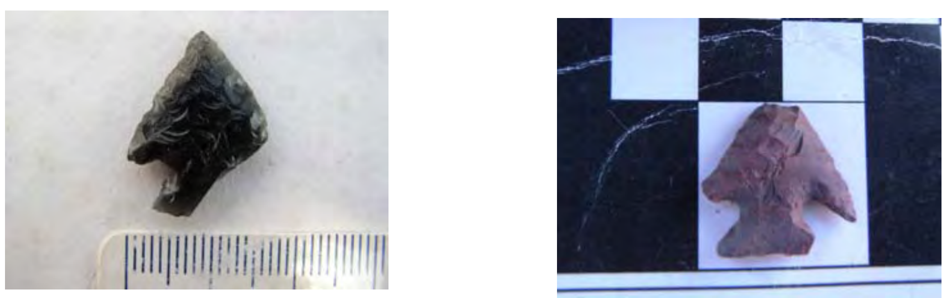


Figure 4.3 Two projectile points from 48PA2811 diagnostic of the Late Archaic, scale as shown.

Based on the artifact assemblage and distribution, the surface component in the eastern portion of the site basin appears to have been relatively stable since the Late Archaic. Features present in the western portion of 48PA2811 indicate a different landscape history. Sedimentation occurring in the western portion of the site has allowed for subsurface preservation of a hearth feature (Feature 1, located in Profile section 1 in Appendix B) and burned bone/chipped stone concentration (Feature 2, located in Profile section 3 in Appendix B). These features are located approximately 120 m northwest of the main surface artifact concentration (Figure 4.1).

Feature 1 is located in a sandy loam deposit 1.2 m below the present surface in the Piney creek-bank. This hearth contains local stones averaging 12 cm in maximum diameter. Figure 4.4 is a photograph of the hearth prior to excavation. The remaining hearth stones still preserved in the creek bank represent approximately three quarters of the total hearth and weigh a total of 148.3 kg (327 lb). These stones were left at the site.

Figure 4.4 Photograph of Feature 1.
Note pieces of burnt log still present in the feature. Feature's length is approximately 80cm.

Oxidation stains in the sediments surrounding the hearth are evidence that this feature was buried in-situ. These stains are a result of contact with direct heat from the fire. Radiocarbon dates for the hearth are listed in the Table 4.1. Dates from the outer growth rings of a burned log located in the hearth most accurately reflect the time of occupation and construction of the hearth (data for radiocarbon dates are listed in Appendix G). Calibrated radiocarbon dates associate the hearth with the Late Prehistoric period. Feature 1 thus represents a more recent occupation than the surface component. This supports the notion that the eastern and western portions of the basin have experienced very different depositional histories.

Table 4.1 Radiocarbon dates for buried soils at 48PA2811. CALIB version 5.0 (Stuiver and Reimer 1993; Stuiver et al. 2005) was used for calibration based on calibration data from Reimer et al. (2004).

Sample number	Sample location	^{14}C age yr BP	2σ cal age ranges	Relative area
Beta-206176	heart wood on log segment from hearth	1550 +/-90 BP	1687-1295	0.988
Beta-206177	outer growth layers of same log	1100 +/-60 BP	1171-925	1
Beta-206178	outer growth layers of different log	1040 +/-60BP	1067-794	1

The second buried feature, Feature 2, is located within the modern A horizon. This feature has not been dated, but a more recent age for this occupation is expected due to its stratigraphic location within the profile (refer to Profile section 3 in Appendix B).

Figure 4.5 Photograph of Feature 2.

This feature is a concentration containing burnt bone, charcoal, quartzite and chert debitage. These remains are very fragmentary, and due to the small pieces of charcoal, bone, and lithics that are still preserved and the discreteness of this layer in the profile, the archaeology was most likely buried in-situ (see photograph in Figure 4.5). Subsequent down-cutting by the stream and the resulting erosion of the stream-bank has destroyed portions of both occupations represented by Features 1 and 2.

In addition to the archaeological features found in the creek bank, a forelimb of *Bison bison* was found eroding from the creek bank (see Profile section 3 in Appendix B). The exposed remains include a humerus with carnivore modification on the proximal surface, a radius/ulna, a metacarpal, the fused second and third carpal, an ulnar carpal, and first phalanx. Dates for Feature 2 and the remains of the *Bison bison* were not obtained for this study. Bison bones were left in-situ in the cutbank but were removed when the site was looted by unknown individuals.

The Geomorphology and Stratigraphy of 48PA2811

The differences between archaeological context on the eastern versus on the western portion of the site can be elucidated by local geomorphology. Debris flows have created hummocky topography found throughout the Piney Creek drainage, and the location of 48PA2811 is a combination of both active and stable surfaces due to these topographic variations. The slopes to the north of the site (see photograph in Figure 4.6) and the low ridge on the southern border of the site basin (refer to the site map in Figure 4.1) share characteristics that suggest these are older stable landforms. These landforms are composed of deposits containing large boulders in a sandy loam matrix. *Picea* *engelmannii* thrive on these ridges and some of these trees, like the one pictured in Figure 4.6, measure nearly two meters in diameter at the trunk base. An additional indication of surface stability and greater landform antiquity is the accumulation of $CaCO^3$ one meter below the present ground surface observed along the southern ridge. These accumulations form a crust beneath and around boulders that support the ridge and are exposed along the Piney creek bank.

Figure 4.6 Photograph of site 48PA2811 facing south.
Photo was taken from the northern ridgeline bordering the basin of site 48PA2811 after the forest fire of 2006. Note deposits of large angular boulders.

The basin portion of site 48PA2811 is believed to be a sag pond that is no longer active. Over time, sediments have collected in this basin, primarily in the western portion of the site. These sediments likely originated from the slopes at the northern portion of the site due to slopewash and also from upstream of Piney Creek and Tributary A.

Deposition has led to the burial of archaeological contexts in the western portion of the site.

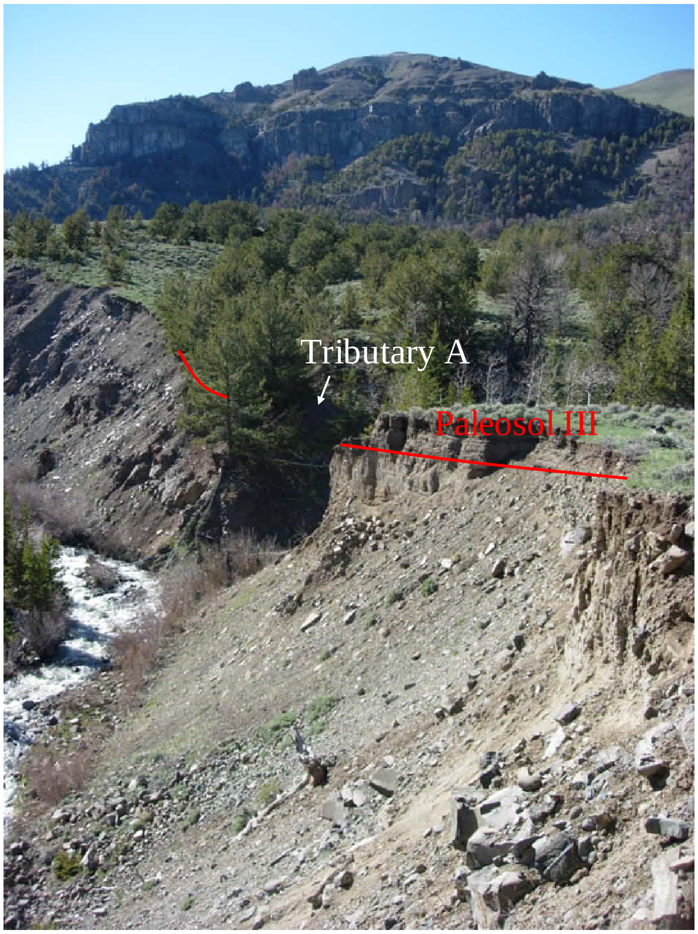


Figure 4.7 Photograph of Piney Creek cutbank.

The western portion of the basin is both an area for deposition of sediments eroding from higher areas and an area of water accumulation and ponding through time. Erosion along the creek bank has exposed a series of buried soils and deposits as well as the cultural features mentioned above. The sequence of buried soils and deposits forms a basin-like profile, measuring between to 2.5 meters in depth that makes up the profile sections mapped in Appendix B. The photograph in Figure 4.7 outlines the bottom paleosol in the basin-shaped deposit sequence. The sequence of soils and deposits becomes essentially pinched off just to the southeast of the mapped profile. This marks the transition between this depositional zone and the comparatively stable southern ridge. Northeast of the creek bank, the stratigraphic sequence is abruptly cut-off by Tributary A (Figure 4.7). However, above the northwest bank of tributary A, the bottom-most paleosol in the profile surfaces. The remnant sag pond that formed the basin-shape profile once filled the area now containing tributary A.

A deeper stratigraphic context of the Piney Creek exposure is presented in a composite profile in Figure 4.8. The bottom most layers shown in the composite, over five meters below present ground surface, are gravel and sand rich sediments that were likely deposited by the creek. These layers continue to a depth of at least 12 meters below the present ground surface and possibly more, though a view of the deeper stratigraphy is obstructed by eroded deposits along the creek bank. A debris flow deposit overlies these fluvial deposits in the profile. The deposit represents a very rapid event based on the diversity in size of materials—some boulders are over one meter in diameter while others are gravel-sized. The matrix of the debris flow is a sandy loam. Soil analyses in the following sections are confined to layers above this debris flow deposit. The reason for focusing on the uppermost deposits, the first 2.5 m in the profile, is that these deposits are where the cultural materials and buried soils are located.

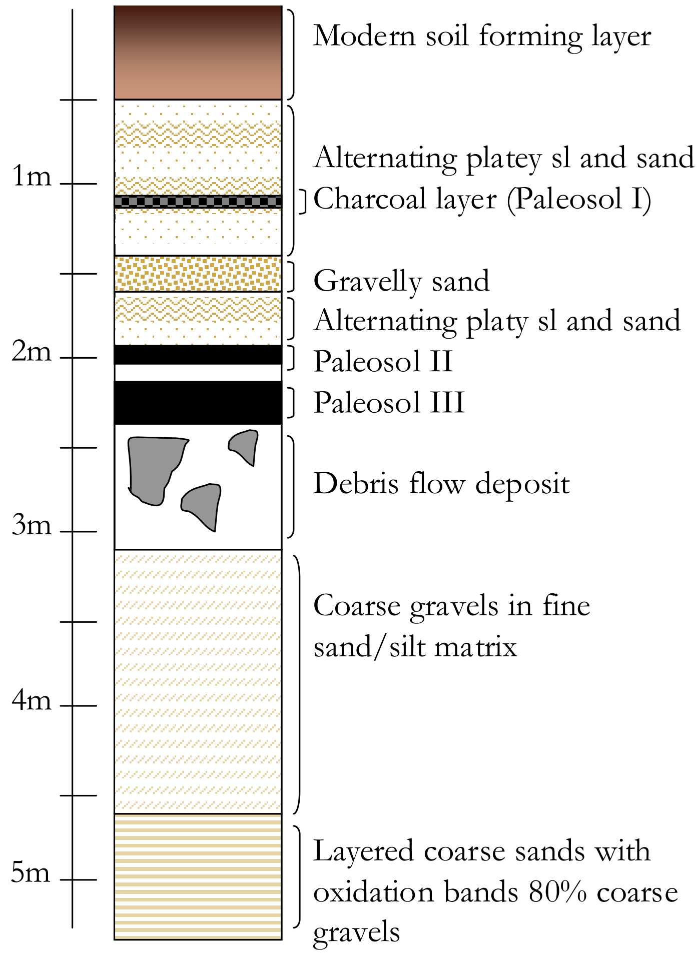
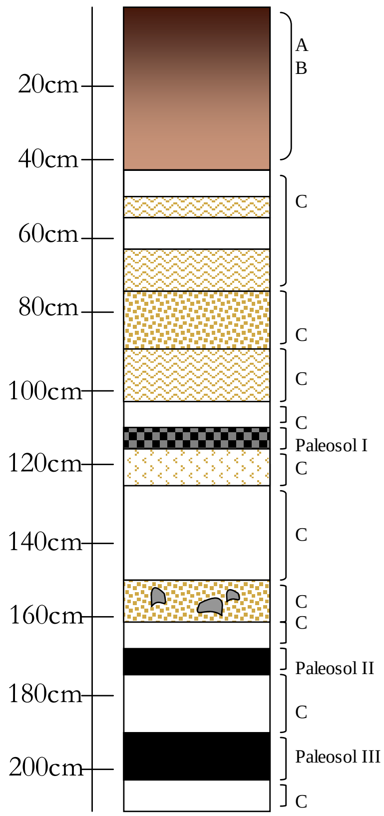


Figure 4.8 A composite of the stratigraphy at 48PA2811.

A composite showing the cultural and soil-forming layers in the Piney Creek cutbank is shown in Figure 4.9. Based on visible differences in structure, composition, texture, and color, four different periods of soil development and multiple depositional events in between the soil-forming periods are indicated. Each layer is referred to as a soil-forming layer or a C (parent material) horizon. Parent material in this example is always a depositional layer.



Depth cmbs[a]	Color Dry	Moist	Texture[b]	Structure[c]
0-13	10YR4/2	10YR2/2	sl	1cogr
13-42	10YR4/2	10YR2/2	sl	2copr
42-50	10YR5/2	10YR4/2	sl	3vcpr
50-54	10YR5/2	10YR4/2	sl	2vkpl
54-66	10YR5/2	10YR4/2	sl	3vcpr
66-76	10YR5/2	10YR4/2	l	2tkpl
76-89	10YR5/2	10YR4/2	s	sg
89-104	10YR5/2	10YR3/2	l	2vkpl
104-111	10YR4/1	10YR2/1	sl	1vkpl
111-116	10YR4/1	10YR3/1	cl	2cosbk
116-124	10YR5/2	10YR4/2	ls	sg
124-150	10YR5/2	10YR4/2	sl	2copr
150-161	10YR5/2	10YR3/2	s	sg
161-169	10YR5/2	10YR3/2	sl	2tkpl
169-176	10YR4/1	10YR3/1	scl	2copr
176-190	10YR4/2	10YR3/2	sl	2copr
190-202	10YR3/1	10YR2/1	scl	3copr
292+	10YR4/2	10YR3/2	sl	2vcsbk

Figure 4.9 A composite of soil sequences at 48PA2811.
[a] cmbs-centimeters below present ground surface
[b] sl, sandy loam; l, loam; s, sand; cl, clay loam; ls, loamy sand, scl; sandy clay loam
[c] grade: 0-structureless, 1-weak, 2-moderate, 3-strong; size: co-coarse, vc-very coarse, vk-very thick, tk-thick; structure: gr-granular, pr-prismatic, pl-platy, sg-single grain, sbk-subangular blocky
Soil color determined by Munsell Color 1975, texture based on results from hydrometer method and soil grade, size and structure based on field observations outlined by Schoeneberger et al. 2002.

Dry and moist color was recorded and is presented in Figure 4.9. Hue is 10YR followed by value/chroma. A generally low chroma throughout the profile is a result of the Absaroka volcanic parent material. Dark colors usually imply organic materials and color was the initial indicator of a buried soil. The paleosols have a chroma 1 with values of 3 or 4. The dark color does not fade with depth indicating that even older soils like PIII are well-preserved.

Soil texture varies throughout the profile. The general matrix is a sandy loam. Depositional layers at 80 cm, 120 cm and 150 cm below surface (cmbs) (Figure 4.9) are nearly devoid of any fines. The deposit at 80 cmbs consists of over 90% coarse sand and small rounded gravels. The deposit at 150 cmbs contains large clasts and coarse sand. These deposits reflect high energy depositional events in comparison with the platy-layered sands and fines present at 46-76 cmbs and again at 89-104 cmbs. These layers are typically more clay rich and range in texture from sandy loam to loam. These horizons are platy in structure and the larger grained particles are prone to erosion. Throughout the horizontal length of the profile this horizon has collapsed or little shelves are created where sediment has eroded away (Figure 4.10). The deposition of these finer-grained particles is expected from a low energy environment and probably occurred when the basin was filled by a pond.

Structure in the profile varies from prismatic or subangular blocky to platy or no structure at all. Platy structure is common in deposits that alternate from high-clay to high-sand (Figure 4.10). This variation might be a seasonal trend in deposition but is undetermined at this time. A granular structure is typical of A-horizons (Schaetzl and Anderson 2005) and occurs in the modern A horizon. Prismatic structures are typical in buried soil horizons and some of the depositional zones. Single-grained deposits (having no structure) are coarse-grained with gravel inclusions.

Figure 4.10 Close-up photograph of platy soil structure.
Note coarser grained sand deposits in between sandy loam.

In general, soil-forming layers are weakly developed throughout the profile section. The modern A horizon is thick but this soil shows little pedogenic activity in the B horizon. The division between the A and B horizon is marked by only a change in structure from granular to prismatic. The first paleosol indicated in the profile (paleosol I or PI) is a burnt A horizon indicated by concentrations of charcoal. This paleosol generally appears at around 110 cm below surface throughout the cutbank. Paleosol II (PII) has higher clay content and is also rich in charcoal but not to the extent of PI. This horizon is separated from paleosol III (PIII) by a sandy loam typical of profile. PIII is the thickest of the buried soils and also contains charcoal.

Charcoal fragments from PI were identified as *Picea engelmannii* based on resin canal distribution, grain size and structure, and growth rings. *Picea engelmannii* is also the same wood found in the hearth. This species is the most common species found in the alpine-subalpine zone of the study area today.

To provide temporal control for the stratigraphic sequence, radiocarbon samples were taken from PI and the bottom paleosol (PIII). The results are presented in the Table 4.2 below. These results are based on charcoal fractions in the soil and provide a minimum date for soil formation and a maximum date for the sediments that overlie these soils. Paleosol III provides dates of approximately 2500 years BP. This relatively young age is unexpected based on the amount of sediment accumulation. Paleosol III is more than two meters below the surface. Paleosol I produced dates close to 900 years BP. Paleosol I is directly above the hearth feature in the stratigraphic profile, and these dates correlate well with the stratigraphic relationships. Dates provided by these paleosols indicate rapid and repeated cycles of sediment accumulation and pedogenesis throughout the history of the profile.

Table 4.2 Radiocarbon dates for buried soils at 48PA2811.
CALIB version 5.0 (Stuiver and Reimer 1993; Stuiver et al. 2005) was used for calibration based on calibration data from Reimer et al. (2004).

Sample number	Sample location	^{14}C age yr BP	2σ cal age ranges	Relative area
Beta-222040	Paleosol I, profile 1	907+/-40	917-739	1
Beta-222042	Paleosol I, profile 2	880+/-40	915-699	0.991
Beta-222039	Paleosol III, profile 1	2620+/-50	2852-2510	0.88
Beta-222041	Paleosol III, profile 2	2480+/-40	2719-2365	0.918

Laboratory Analyses Results

Laboratory results from bulk soil samples taken from the profile are presented below in graphical form. Results for selected samples taken directly above, below and in the soil-forming layers in two different sections of the profile, referred to as profile 1 and profile 2, are also presented. The locations of these sampled areas are on the profile map in Appendix B. Values for organic carbon, inorganic carbon, and nitrogen totals are shown as percentages. Texture values are presented as a clay-free index:

$$\text{Clay-free index} = (\%\text{silt} + \%\text{sand})/\%\text{sand}$$

where values equal to one are a hundred percent sand. All values for sand, silt and clay are in Appendix D. A spreadsheet of all laboratory results is in Appendix F.

The amounts of carbon and nitrogen in buried soils are dependent upon the environment prior to burial, the circumstances of burial, and the biological activity within the buried soil, thus the best conditions for preservation of organic matter are rapid burial (Stevenson 1969). Amounts of organic carbon and nitrogen do not seem to decrease with depth, and due to the high rates of deposition, the buried soil layers are fairly well-preserved. Organic carbon and nitrogen are nearly perfectly correlated and high values of organic carbon and nitrogen typify the buried soils and the A-horizon of the modern soil. These values vary among the soil-forming layers and PI and PIII contain the highest percentages of organic carbon and nitrogen. There are also slight pulses in organic carbon and nitrogen percentages in depositional layers between 40 and 75 cmbs. These pulses correspond with the platy clay/sand layers that are believed to be pond deposits. Very low values in carbon and nitrogen reflect coarser-grained depositional layers in the profile.

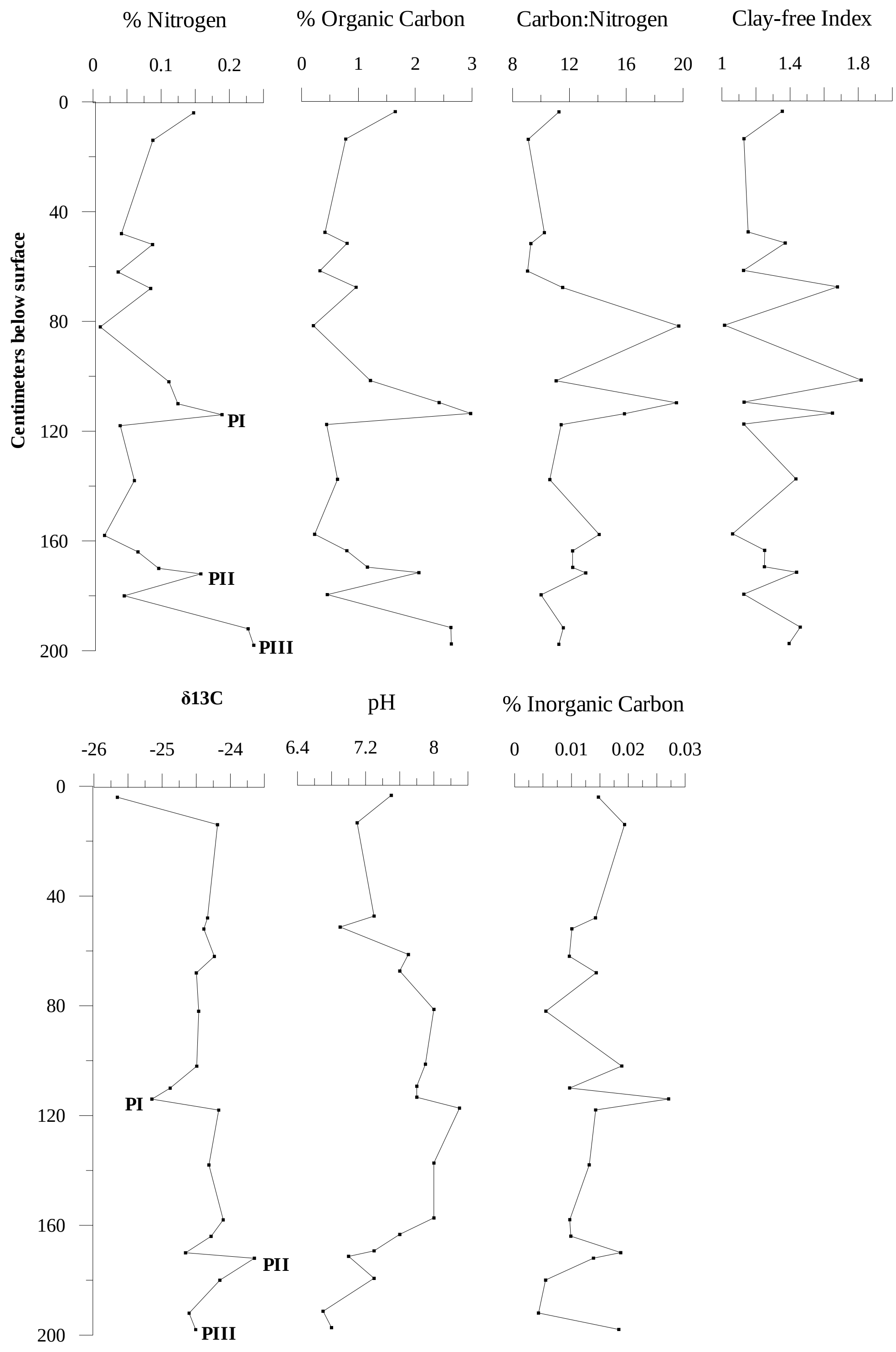


Figure 4.11 Laboratory results from bulk soil samples.

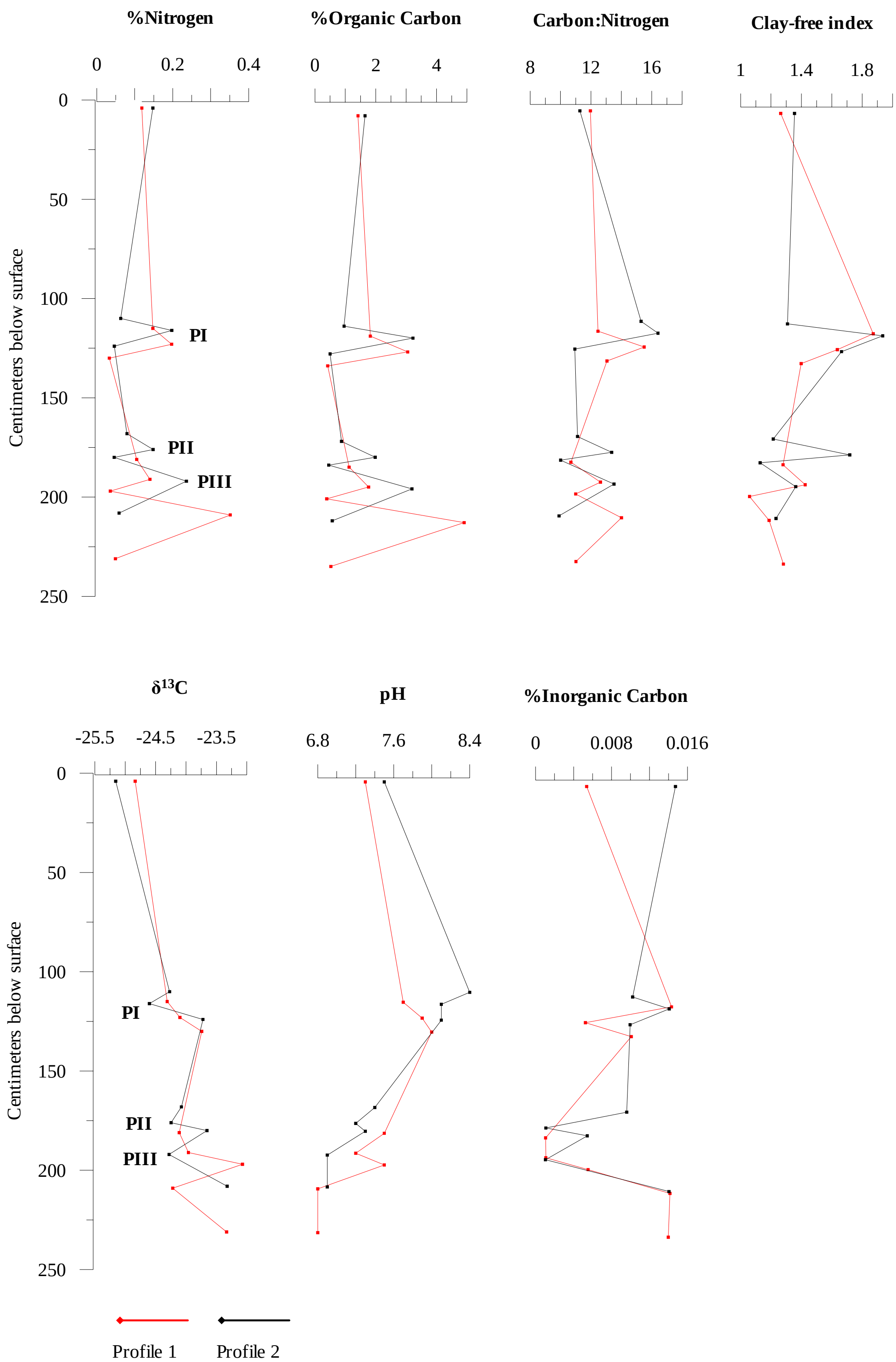


Figure 4.12 Laboratory results for profiles 1 and 2.

Higher percentages of carbon and nitrogen might be expected to correlate with a higher amount of fines as increased surface area tends to retain water and nutrients (Schaetzl and Anderson 2005). Thus, a higher clay-free index should correspond with higher organic carbon and nitrogen percentages. Based on the results illustrated in Figure 4.11 and 4.12, there is no significant correlation between organic carbon and nitrogen and the clay-free index. This is in part due to the lack of a large pulse in organics from the more clay-rich layers between 40 and 75 cmbs. Higher values for fine-grained material do not necessarily mean high organics, and these layered deposits seem to be more indicative of low-energy deposition instead of soil-forming layers. Another reason for a lack in correlation is due to clay-free index values for PI. These values are variable. This was a sampling issue as PI is a very thin deposit and overlying coarser sediments may have mixed with the upper portion of this soil.

Ratio values for organic carbon and nitrogen are listed in Figure 4.11 and 4.12. The ratio of carbon to nitrogen is a comparison of production versus decomposition of plant material in soils. Paleosol I has the highest C:N ratio of the soil-forming layers—just above 19. This is typical for forest A horizons which have C:N ratios in the order of 20:1, while a grassland A horizon ranges from 8:1 to 15:1 (Brady and Weil 2002:506-507). High C:N ratios in buried soils can also result from the cessation of microbial activity brought on by rapid burial (Catt 1990). There is an overwhelming presence of charcoal in PI, and rapid burial of this soil surface helped to preserve this organic litter. A depositional layer at 80 cmbs also produces a C:N ratio of over 19. The percentage values of organic carbon and nitrogen are extremely low in this deposit, unlike the buried soils, and the C:N ratio for this depositional layer is indicative of trace organics that were carried with these sediments and deposited. Both PII and PIII have a C:N ratio similar to the present day soil-forming layer, with a slightly higher C:N ratio for PII. The low C:N ratio of PIII may indicate a more herbaceous vegetation community.

The $\delta^{13}C$ signal shown in Figure 4.11 and 4.12 indicates that the ratio of C_3 to C_4 plants was fairly consistent through time with a dominance of C_3 plants. Values vary, but typically C_4-dominated communities (such as prairie or steppe) have a $\delta^{13}C$ value of -12.0‰ while C_3-dominated communities (like forests and shrublands) have a value of around -26.0‰ (Bender 1968). There is some variability in these values among the buried soils. In general, the $\delta^{13}C$ of soil organic matter should increase with depth in soil that has remained under the same plant community during a long period (O'Brien and Stout 1978). Both the modern soil forming layer and PI represent the lowest $\delta^{13}C$ values. PIII shows slightly higher values, but $\delta^{13}C$ values for PII are highest. The PII soil may have supported vegetation with a higher proportion of C_4 plants (Nordt et al. 1994). Alternatively, the higher $\delta^{13}C$ value for PII may indicate a time of drought stress (Stevenson et al. 2005). To check this hypothesis, one can look at the C:N ratio of PII. PII shows less nitrogen, indicated by a slightly higher C:N ratio. A higher C:N ratio does not correspond with an increase in grasses, thus it is suggested that PII represents a period of more xeric conditions at the site.

Soil pH lingers around neutral to slightly alkaline through profile (see Figure 4.11 and 4.12). Often high pH is related to $CaCO_3$ accumulations, but there is no significant correlation between inorganic carbon and pH (R-squared value of .0029 shows no real relationship). Based on inorganic carbon values listed in Figure 4.11 and 4.12, there is only a slight trace of inorganic carbon through the profile. The higher values of pH can be the result of many other factors. Higher pH, however, is not atypical for the region. In an investigation of soils in the Sunlight Basin, to the north of the Upper Greybull study area in the GYE, Huckleberry (1985) hypothesizes that neutral pH and a decrease in pH with depth reflects pedogenic immaturity. This makes sense in comparing PIII, which has the lowest pH values, to PI, which has the highest values. PIII has the thickest soil horizon in the profile while PI shows up as a very thin horizon in the profile. While the amount of inorganic carbon is extremely small, the graph indicates a slight increase in inorganic carbon in the soil-forming layers compared to the depositional layers. Slight traces in inorganic carbon likely represent pedogenic carbonates produced during the incipient stages of soil formation (Monger 2002). Soils had little time to develop $CaCO_3$ horizons due to landscape activity.

INTERPRETATION

Environmental and Archaeological History of 48PA2811

By combining results from archaeological, laboratory, and field data analyses, a phase by phase story of landscape change is developed. Landscape change at 48PA2811 is cyclic, characterized by stages of soil formation, disturbance, and rejuvenation. The landscape has repeated the cycles at least four times. While each cycle is not necessarily the same, they tend to repeat specific phases.

Phase I

Through geologic time, many changes have occurred on the landscape where site 48PA2811 now exists. Many of these changes, for many reasons, can not all be reconstructed. I begin this phase by phase account of landscape change with the extended period of deposition that is indicated in the deep stratigraphic deposits of the Piney Creek profile. This period predates 3,000 years ago. During this time, the creek was nearly to the level of the contemporary site basin. Some of the mass-wasting events that now shape the local topography had not occurred, though the large colluvial slopes surrounding the site basin were probably present. Deposition during this phase was dominated by fluvial activity and these sediments accumulated to form the thick stratigraphic deposit. Phase I is illustrated in Figure 4.13. There are no absolute dates for this phase, but it was likely a prolonged period. Towards the end of this phase, it is likely that people were using the drainage basin. Sites that contain Archaic projectile points exist along the upper reaches of the Piney Creek drainage and adjacent to 48PA2811. One projectile point found within the Piney Creek drainage may be associated with the Early Archaic.

Phase II

The second phase of landscape change is a disturbance phase, dominated by debris flow events. The source areas for the debris that accumulated in the creek-bank profile are the colluvial/slopewash and bedrock slopes to the north and northwest of the site area. It is very likely that the bulk of debris flow material originated near the headwaters of the tributary creek (Tributary A) that now joins Piney Creek northwest of 48PA2811 (Figure 4.1). The landscape during and shortly after these events was very active with fresh rubble exposed and running water. These events resulted in the hummocky topography of 48PA2811, creating sediment caches within the site area. An illustration of Phase II is pictured in Figure 4.13. These debris flow events likely occurred close to 3,000 years ago.

Phase III

The disturbance regime of Phase II resulted in sediment influx promoting soil development. Phase III represents a period of rejuvenation marked by soil formation and the reorganization of local vegetation. Soil formation began sometime before 2500 years BP as indicated by radiocarbon dates from charcoal samples in PIII. Paleosol III is a dark, thick soil horizon high in organic carbon. The structure of the vegetation community at this time was probably very similar to today's forest/basin vegetation as indicated by the carbon to nitrogen ratios and $\delta^{13}C$ values. Phase III is pictured in Figure 4.13.

During Phase III, people visited the site basin. Lithic debitage and tools scattered throughout the site area indicate that flint knapping occurred at 48PA2811 sometime during the Late Archaic. Fire-cracked rock found within this surface cultural component is not necessarily cultural. There are no other archaeological features present on the surface to indicate how the site was used during this occupation.

Phase IV

Phase IV is period of disturbance beginning with a fire event that weakened the soil formed during Phase III. This fire occurred sometime after 2500 BP. Fires instigated localized deposition and perhaps shallow debris flows (Figure 4.13). These disturbances allowed for sediment influx and the rapid burial of PIII.

Phase V and Phase VI

Phase V is a period of reorganization and pedogenesis following the fire in Phase IV. Essentially Phase V is a repeat of Phase III with some subtle differences. Paleosol II is created during this phase and local vegetation was similar to the modern communities, but there is an indication that this phase underwent a period of drought stress. There are no absolute dates for this phase, but based on its place in the profile, PII likely formed between 2,000 and 1,500 years ago. This period of relative stability, indicated by the soil formation, does not appear to have lasted long. Phase V is interrupted by another fire. This disturbance is phase VI. Phase VI is a repeat of Phase IV. The arrows in Figure 4.13 indicate the cyclic nature of these phases.

Phase VII

Following the second fire event (Phase VI), a sequence of different depositional events occurred. These events were not as dramatic as the disturbance period described in Phase II, though one of the deposits suggests a period of high energy deposition based on the presence of 10 cm diameter clasts. Sometime toward the end of this phase, people used the basin area and constructed a fire hearth (Feature 1). The hearth was used one time or over a short period of time, being re-fueled perhaps once or twice. The wood used to fuel the fire was *Picea engelmannii*. Stones for the hearth's construction were easily acquired nearby and were piled onto burning wood. It is uncertain if the sag pond in the site basin was active during this phase. Phase VII is pictured in Figure 4.13.

Phase VIII and IX

A third soil-forming phase characterizes Phase VIII. This is again a repeat of Phase III and V. Paleosol I is however, the most weakly developed of the soils and was rapidly buried by sediments after it was burned. This soil development occurred around 950 yrs BP. The fire event that follows is Phase IX. Both Phase VIII and Phase IX are shown is repetitions in Figure 4.13.

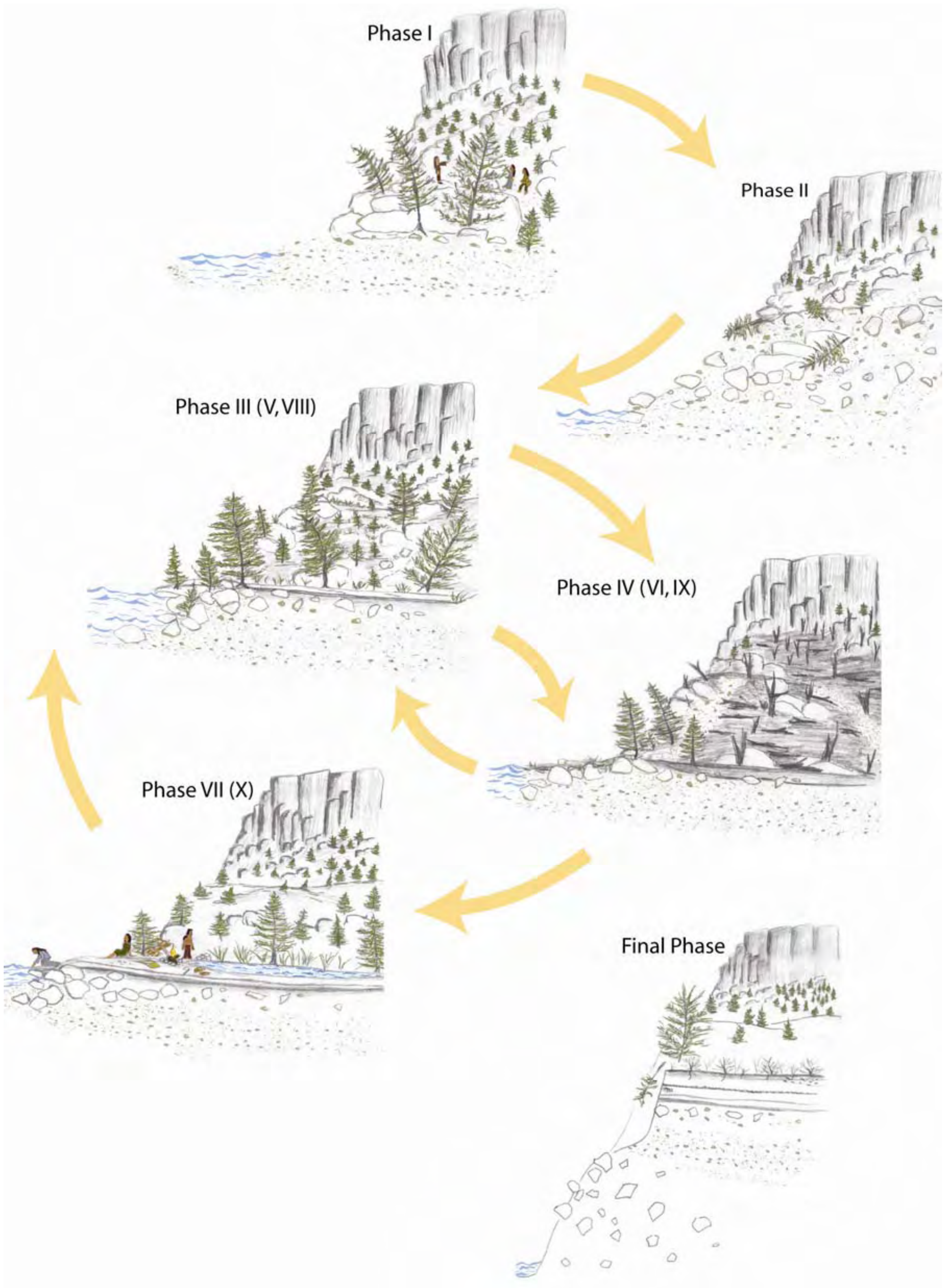


Figure 4.13 Landscape phases for site 48PA2811.

Phase X

The period that follows the formation and burning of PI is referred to as Phase X. This is a period of slow, cyclic deposition of sands and clays in the sag pond that occupied the basin. People returned to the site, as indicated by Feature 2. Feature 2 is a shallow cultural deposit of burned bone fragments, charcoal, and lithic debitage and likely indicates that food was prepared at the site location. Phase X is represented as a repeat of Phase VII in Figure 4.13. A period of soil formation began between Phase X and continues today.

Final Phase

The extreme down-cutting of Piney Creek and Tributary A is a fairly recent phenomenon, occurring sometime between 900 years ago and the present. The down-cutting has exposed the creek-bank profile seen today. The steepening of the bank by the creek's incision has led to the rapid erosion of the bank. *Picea engelmannii* that once lined the bank and large clasts have eroded. Factors attributing to this rapid down-cutting are unknown. The high rate of landslides in the region may play a role in river incision, bringing large amounts of sediment into the creek and disrupting the creek's flow and sediment carrying capacity (Ouimet et al. 2007). The Final Phase pictured at the bottom of Figure 4.13 reflects the present condition of the creek bank at 48PA2811.

The Final Phase is only final in regards to this thesis. The present condition of the 48PA2811 is subject to change once again by another set of disturbance regimes. The forest and basin containing 48PA2811 burned in 2006. The impact that this event will have on the landscape is not yet known but; based on past evidence, erosion and deposition will follow. Small-scale erosion, in the form of small flows measuring approximately one meter in maximum width, was observed along the slopes surrounding the site basin in September of 2006 shortly after the wild fire. It is likely that these processes will continue to weaken the creek bank.

Human activity at 48PA2811 and the surrounding area also continues. A modern cattle and hiking trail border the site. This trail, which is used often by hunters during the late summer and early fall, follows Piney Creek up to Piney Pass, the major divide of Carter Mountain, which separates the drainage basins of the Greybull and the North Fork of the Shoshone River. The strategic location of 48PA2811 along Piney Creek and the gentle topography of the site are likely reasons for the return of people to the site throughout its history. In addition to these qualities, the site basin offers vegetation that was an attractant for animals like bison in the past and deer and moose today.

The results from the multiple analyses of site 48PA2811 indicate a landscape history of local cycles and transformations. This history shows the complexities of soil formation and deposition sequences in a landslide feature in a subalpine environment. 48PA2811 is unique in the information that can be derived from the subsurface deposits. The buried contexts associated with 48PA2811 have not been encountered upstream or downstream on Piney Creek, indicating that very localized processes have led to the preservation of this site. However, the stratigraphic integrity found at 48PA2811 may not be exclusive to this site. Across the Upper Greybull numerous archaeological sites are associated with a diversity of landforms, some very similar to those occurring along Piney Creek. These associations need to be examined because they can provide information on landscape change across the region. The following section discusses some of the parallels between mass-wasting features and archaeology across the Upper

Greybull landscape and what information can be provided from these numerous associations.

LANDSCAPE CHANGE ACROSS THE UPPER GREYBULL

Regional Mapping and GIS

Mass-wasting features dominant the Upper Greybull landscape and archaeological contexts. The investigation of 48PA2811 exemplifies how this relationship can provide environmental data relating to landscape change and information regarding archaeological preservation. This section looks at the relationship between mass-wasting and archaeology on a regional scale. The Wyoming State Geological Survey and the Water Resources Data System have mapped over 1090 separate “landslide” features in the Upper Greybull. The diversity of mass-wasting features was previously discussed in Chapter 2 but will be drawn upon again. All landslide data and ArcGIS output is listed in Appendix H.

To examine regional relationships between landslides and archaeological sites, I used a sample of 148 archaeological site polygons mapped in the Upper Greybull. A total of 99 archaeological sites are located on mass-wasting remnants in the study area. This sample indicates a significant relationship. Table 4.3 shows the area shared by archaeological sites and landslides based on calculations produced using the intersect tool in ArcGIS. The number of archaeological sites occurring on specific landslide surfaces is indicated under the frequency column in Table 4.3. For example, 28 archaeological sites occur on multiple slump/flow (ms/f) surfaces, covering an area of over 200,000m^2. Based on the results listed in Table 4.3, over 50% of all sites for this study occur on a slump/flow surfaces. In contrast to the popularity of slump/flow surfaces, only one archaeological site is located on a Quaternary talus/rockfall/rockslide (Qt/rf/rs) formation. A number of sites also occur on rock glacier formations (rgi, rg).

Table 4.3 Occurrences of archaeological sites on mass-wasting landforms in terms of frequency and area.

Landform	Area m^2	Frequency
ms/f	245360	28
s/f	79084	19
older flow	39803	5
af/df	29742	10
ms/mf	27113	7
Rgi	23454	8
Df	17149	1
rg/rs	12766	4
mdf/af	7106	1
mdf/sw	6305	1
rs/df	4119	1
rf/rs	3140	1
Mf	2990	2
mrs/mf	2757	2
af/mdf	2116	2
F	2099	2
mblsl/mrs/mf	1965	1
s/rs	1368	1
S	392	1
rs/af	278	1
Qt/rf/rs	90	1
Totals	509193	99

Factors attributing to the variety of surfaces used and the high frequency of sites on slump/flows are many. Landslide deposits provide surfaces that are acceptable as camp locations. One of the multiple slump/flow formations that contains many archaeological sites is an area referred to as 'Jack Creek flats'. This is an open, low sloping terrain with exceptional views of surrounding drainages, many sag ponds, and today large herds of cattle and elk graze. The slump/flows that make up Jack Creek flats appear to have a long history of surface stability producing many archaeological associations. Landslides enhance biophysical and thus biological diversity which may had made them attractive locations for animals as well as humans. Landslides also expose and deposit lithic resources. Talus features and rock slides are not ideal for camp sites, but rock structures have been found on some of these features (Kinneer 2007). Occupations on rock glacier surfaces near Dollar Mountain indicate lithic procurement of locally derived materials (Reitze 2004).

Based on the subsurface deposits at 48PA2811, the common occurrence of archaeological sites on multiple slump/flow surfaces indicates great potential for subsurface preservation of archaeological and environmental data across the Upper Greybull. Sag ponds, both active and inactive occur across many of these features. Excavations on an older remnant flow surface in the summer of 2006 at site 48PA2874 indicated that sag ponds are ideal microenvironments for archaeological recovery in the region, not just at 48PA2811 (Bechberger and Todd 2006).

Identifying when landslides occurred is crucial for understanding distribution of archaeological sites across the Upper Greybull landscape and also for understanding larger landscape processes. Just as different layers of deposition can be distinguished at 48PA2811, different pulses in landslide activity across the Upper Greybull can be identified by use of the archaeological record. Mass-wasting features associated with glacial/pluvial cycles may have been reactivated during Neoglacial advances and retreats. While the advancing and retreating of rock glaciers has the potential to wipe out early sites, temporally sensitive archaeology located within and around these features may indicate when surfaces were stable (Reitze 2004).

Projectile points do not provide absolute dates, but they are commonly used as chronological markers when cross-dated with regional chronologies (Burnett 2005).

Many projectile points identified in surface surveys throughout the Upper Greybull are on mass-wasting features. These associations are listed in Table 4.4 based on number of associations and specific projectile point.

Table 4.4 Cross-dated projectile points associated mass-wasting features

Projectile points	Af/df	df	f	Mdf/sw	mf	ms/f	ms/mf	older flow	rgi	s/f	Totals
Unspecified		1				15	2	4			22
Late Prehistoric	4		1		1	38		2		1	47
Late Archaic/Late Prehistoric						2					2
Not Late Prehistoric						5					5
Late Archaic	3					36	2	6	1	5	53
Middle Archaic						4		4			8
Early Archaic						2		2	1		5
Unspecified Archaic	1		1	1		17	1	5	1	3	30
Paleoindian/Middle Archaic						1					1
Paleoindian						4		2			6
Totals	8	1	2	1	1	124	5	25	3	9	179

Two observations can be made from this table. The first is that some landslide formations appear to be more ancient than others based on continued human occupations since the Paleoindian. Multiple slump/flow complexes on the south side of the Greybull River have produced much archaeological data from the region. Two of these features on Jack Creek flats have evidence for continual use beginning with the Paleoindian time period indicating the antiquity of these land surfaces. This area has been extensively surveyed, and this may be part of the reason for higher frequency of sites and associated stone tools however, the initial formation period for these landforms was before the Holocene. This does not mean that there isn't potential for buried archaeological deposits. As was illustrated by 48PA2811, landslide surfaces are often re-activated periodically. Partially exposed burned bone and artifacts were found within a sag pond on a multiple slump/flow landform on Jack Creek flats, showing the depositional activity has occurred.

A second observation that can be made based on Table 4.4 is that Paleoindian, Early Archaic, and Middle Archaic projectile points are limited to only a few landforms and landform types. During the Late Archaic however, a variety of landslide surfaces were used. In addition to the large ms/f surfaces that were continually occupied on Jack Creek flats, smaller ms/f surfaces near the headwaters of Jack creek show evidence of early occupations. Smaller individual s/f, rg/rs, Qt/rf/rs, af/mdf, and af/df features do not show occupations until the Late Archaic. This may suggest that a period of large-scale surface instability occurred some time before the Late Archaic in the Upper Greybull. The surface instability left numerous smaller landslide remnants that were then subsequently occupied during the Late Archaic and Late Prehistoric. Many of the landslide surfaces used during the Late Archaic are located along the narrow drainages that are prone to erosion. There is the other possibility that this is a pattern of human agency—people did not occupy these locations before the Archaic.

The landscape history at 48PA2811 may attest to a large-scale disturbance regime sometime before the Late Archaic. For 48PA2811 this is represented as Phase II. It is impossible at this point to know if this phase of debris flow events was wide-spread, but based on the landslide data across the Upper Greybull, similar processes are occurring across the Upper Greybull landscape and these processes are likely influenced by the same factors. Relationships between temporally diagnostic artifacts and landslides also suggest a change in landslide magnitude through time. The multiple slump/flows that make up Jack Creek flats appear to be more ancient and they are enormous. Later occupations occur on these large ancient features but they are also present on a variety of smaller landslide remnants. This change in landscape dynamics through time has many ecological implications.

This chapter has presented and examined the results of soil analyses from 48PA2811 and a phase by phase story of landscape change for this site was developed. To compare the site-specific results with the Upper Greybull area, regional landslide and archaeological data was coupled and relationships were identified and discussed. The results support conclusions that the Upper Greybull has been a dynamic and changing region, and the archaeological record can highlight these changes through time. The archaeological record and its relationship with these landslide remnants suggests a change in tempo and magnitude of landslides through time. Paleoindian projectile points occur on ancient and very large slump/flow and older flow features but through time more sites are located on smaller flow events.

The following chapter concludes this thesis. The principle questions asked in Chapter one are re-visited. Additionally, the results of this study, particularly the time-line development by investigations at 48PA2811, are examined in relationship to large-scale change influencing the Greater Yellowstone Ecosystem and beyond.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

The Upper Greybull has experienced a great deal of landscape activity since the formation of the Absaroka Range. Remnant landslide features indicate that large-scale events have continually altered surface geology, topography, hydrologic regimes, and biological communities of the region, impacting the archaeological record over the last 10,000 years. On a much smaller scale, the stratigraphic record at site 48PA2811 indicates that large-scale landslides influence local landscape processes. The investigation of 48PA2811 demonstrates small-scale cyclic events of sedimentation, soil formation, and human occupation over the last 2500 years. This final chapter summarized the questions outlined in Chapter 1 and discusses the regional connections between surficial processes, climate change, and human impacts on the landscape. The chapter concludes with future directions and final thoughts.

Constructing an Environmental History

Chapter one outlined three objectives with a nested set of questions. Each objective and associated set of questions is revisited here.

Objective 1:

Demonstrate how a multidisciplinary approach can be used to develop an environmental history of site 48PA2811.

This objective was achieved through field work, data gathering, and analyses. The multi-disciplinary approach used in this study adopted methods and methodologies from geology, pedology, and archaeology. The first question under this objective was as follows: *How often has the landscape changed through times of human occupation?*

A chronology of 48PA2811 was achieved through projectile point cross-dating, radiocarbon dating of archaeological deposits and organic soil-forming layers. Based on these sequences, a complete cycle of soil formation, fire, and reorganization of vegetation occurs at least once every 1,000 years, with an average of once every 625 years. Over the last 2500 years, four soils (PIII, PII, PI and the modern soil) developed and were subsequently burned and buried. This constant disturbance and recovery regime means that plant and animal communities reorganize and proliferate often. In addition to the cyclic events of soil formation and deposition, the incision of Piney Creek has been rapid and is causing erosion of the bank.

The archaeological evidence at 48PA2811 indicates the first documented occupation at the site was during the Late Archaic (3200-1500 RCBP). Artifacts associated with this occupation occur in the surface assemblage in the eastern portion of the site. This portion of the site has not changed dramatically through time based on the intact assemblage and present of Late Archaic projectile points. Paleosol III produced radiocarbon dates that overlap with the Late Archaic. The next evidence from human occupation occurred at 1070 RCBP based on dates acquired from Feature 1. Feature 1 occurs on a low-energy depositional layer. Between these two occupations, over one meter of sediment accumulated and two different soils formed, burned, and were buried (PIII and PII). This rapid rate of deposition is not expected for a subalpine environment.

After the second occupation, a third soil forming period occurred at around 950 years ago. This soil forming period was followed by another fire and multiple depositional events that buried PI under a meter of sediment. A third occupation occurred, represented by Feature 2. This occupation occurred during, or shortly before, the development of the present day soil at the site location.

The second question under objective 1 asks: *What types of processes are influencing this site?*

Processes occurring at 48PA2811 are cyclic, alternating between periods of disturbance and periods of soil formation. The end of Chapter 4 outlines the different landscape phases occurring at site 48PA2811. The first phase is a disturbance phase marked by a large multiple slump flow event, or events. This multiple slump/flow encompassed the area within and around site 48PA2811. These landslide events shaped the region topographically and geologically, influencing the types of local processes that follow. The resulting topography from the landslide events is a hummocky surface where a sag pond formed and was filled by sediments. Some of the depositional events that followed were high energy with unsorted cobbles and gravels, others were slow and perhaps seasonal, indicated by the platy layers of sand and loam.

Periods of soil formation occurred at the site location. These events are considered times of relative landscape stability and reorganization of plant communities. A complete change is plant community structure at site 48PA2811 is not indicated by properties in the buried soils and modern soil at the site. Carbon isotope values and carbon to nitrogen ratios may indicate a drier period that occurred between 2500 and 950 years ago. Fire has also had a continued influence on the site area. Fire is a likely suspect in initiating higher sedimentation rates and promoting surface instability in the region. At the same time, fire replenishes the soil and allows from vegetation reorganization and recovery.

Objective one included a third question relating to human occupations. This question asks the following: *How can the identification of these processes help in reconstructing past environments before, during and after times of human occupation?*

Topographic and environmental evidence indicates the landscape was different in some ways but also very similar to the landscape seen today at the site. The steep eroded cut bank containing archaeological evidence suggests that the water table was much higher during past human occupations, providing better access to water from Piney Creek. The higher water table and the sag pond indicate that the site may have experienced more lush conditions. The presence of large dead *Picea engelmannii* eroding into the creek today suggests the bank was wooded before erosion impacted the area. Although the basin may have experienced moist conditions in the past, there are also indications that drought impacted the area. Carbon isotopes from PII may suggest a drier period. Further chemical analyses will confirm this and radiocarbon dates from this soil will also tighten this chronology. At this time there is no archaeological evidence coinciding with PII. Whether this is due to the possibility of unfavorable conditions at site 48PA2811 at this time period is purely speculative.

The similarities to today's environment are exhibited in buried soil properties. PIII has similar physical and chemical properties to the modern soil, suggesting that the people who occupied the site during the Late Archaic experienced conditions similar to today. Charcoal from *Picea engelmannii* present in PI suggests that the same tree type found in the site area today was present along the stream bank 950 years ago.

The final question under the first objective is as follows: *How has the archaeological record been impacted by these changes?*

The archaeological record at 48PA2811 is a combination of natural and cultural processes. The topographic configuration of site 48PA2811, the result of multiple slump/flow events, has created different depositional environments within the site boundary. The eastern portion of the site is relatively stable with little evidence of deposition or buried archaeological deposits. The western portion is instable with a high rate of deposition, allowing for good potential of buried materials and a complex stratigraphic record. This difference in deposition has allowed for older deposits (the Late Archaic occupation in the eastern portion of the site) to occur above younger deposits (Feature 1 and 2 in the western portion of the site). This does not follow the expected stratigraphic relationship, and it underscores the importance of understanding landscape change when making archaeological interpretations.

While geologic disturbances have allowed for preservation of archaeological deposits at 48PA2811, these processes are also destroying portions of the site. It is uncertain how much archaeological data was lost due to the eroding creek-bank and how much more will be exposed. Fire has played a role in deposition and based on field observations in 2006, fire not only instigates localized deposition but it changes artifact assemblages in numerous ways. The impact of fire on artifact assemblages can not be addressed here due to the constraints of this study.

Mechanisms for Change

Objective 2:

Demonstrate how the archaeological record can be used to assist other sciences in understanding the frequency and possible catalysts of landscape change in a mountain setting.

A larger spatial and temporal scale was required to address this objective in order to look for patterns of specific landforms associated with sites across the Upper Greybull. ArcGIS was used to assess relationships between archaeological sites and landforms at a scale that encompassed the Upper Greybull area. The first question was stated as: *What types of landscape change dominate the GRSLE study area landscape?*

Based on the Wyoming State Geological Survey and the Water Resources Data System Landslide database (2001), over one hundred different landslide features occur throughout the Upper Greybull area. The most common type is multiple slump/flow events that cover extensive areas across the Upper Greybull. Site 48PA2811 is contained on one such feature, and numerous other sites are located within these features. Although landslides are widespread, it is inaccurate to suggest that these events are the sole dominate form of landscape change. These features are the result of multiple catalysts. Wide-spread mass-wasting has been attributed to glacial/pluvial cycles (Breckenridge 1974; Pierce 1968). In the GYE, localized debris flow events have been the result of wild fires (Meyer et al. 1992, 1995). Climate fluctuations, fire, and mass-wasting are all dominant forms of landscape change in the region and these disturbances have a variety of biotic and abiotic responses.

The second question is stated as: *Are these processes comparable to processes occurring in the surrounding regions?*

The mass-wasting events occurring across the Upper Greybull are comparable to those occurring outside this area. Albanese and Frison (1995) synthesize pollen data and geomorphic data from archaeological sites in the northern Plains region which includes basin areas and mountain areas to look the influence of climate change during the Holocene in mountain environments. The variability shown in their synthesis, Albanese and Frison (1995) argue is based on a small sample size across a geographically diverse region. Sites in Montana, Yellowstone, and the Absarokas show different patterns of landscape change. During the middle Holocene, the Elkhorn Mountains of southwestern Montana show evidence of alluvial fan and debris-flow deposition and an abundance of charcoal grains in alluvial sediments. The Lookingbill site in the Absaroka site shows little change in sedimentary and pedogenic processes throughout the early and middle Holocene. Albanese and Frison (1995) suggest that because the Lookingbill site is located near a natural spring, this microenvironment was somewhat unaffected by regional drying and perhaps a natural attractant for human populations as well. While regional patterns are somewhat spotty, more data and the consideration of microhabitat will allow for future comparisons.

On a shorter time-scale, studies in the GYE have investigated fire-related debris flow sequences (Meyer et al. 1995). Studies by Meyer et al. (1995) are particular applicable to the chronology developed at 48PA2811. Fire-related debris flow chronologies for two sites in northeastern Yellowstone National Park suggest that similarities in timing of debris flow events are due to common climatic controls (Meyer et al. 1995:1211). Figure 5.1 is an image from Meyer et al. (1995) that includes radiocarbon dated fire-related debris flows and probable fire-related debris flows alternating with periods of overbank sedimentation. It is argued that these cycles are

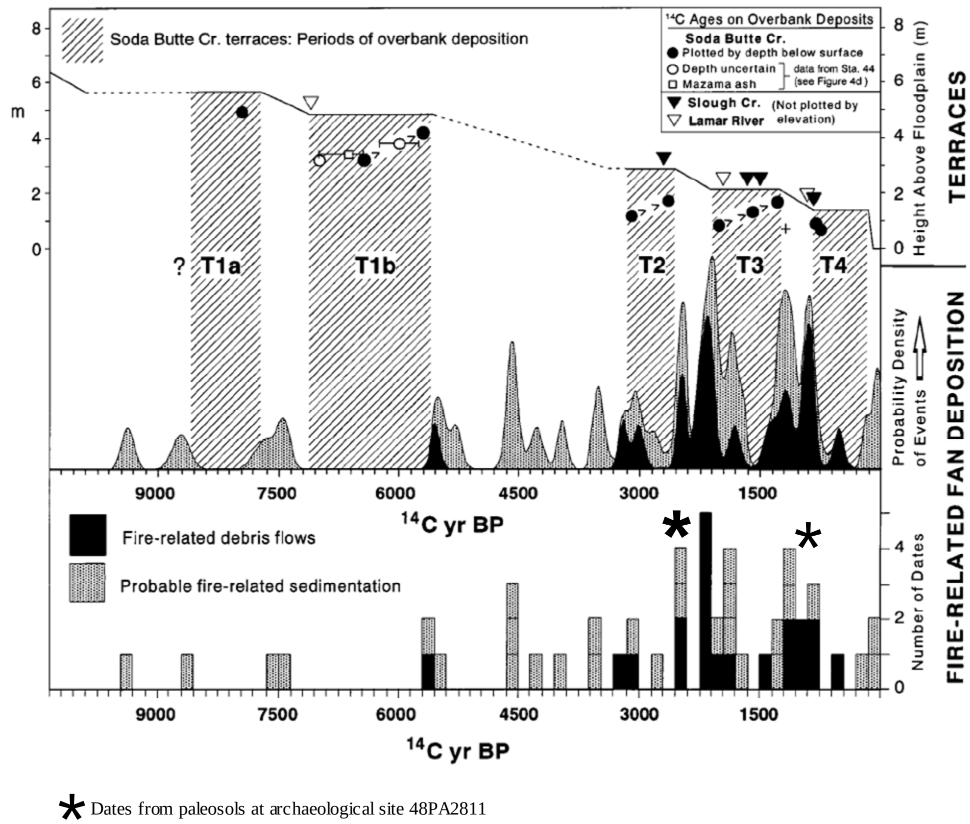


Figure 5.1 Calibrated calendar year chronology of alluvial activity in northeastern Yellowstone National Park.
(from Meyer et al. 1995).

responses to cooling and warming trends during the middle and late Holocene. Periods of warming and drying during certain periods have made the landscape more susceptible to large fires which, in turn, result in landscape instability and mass-wasting (Meyer et a. 1995). The paleosols at 48PA2811 contain evidence of past fires occurring at three different intervals in history (not including the most recent fire in 2006). Dates from PI and PIII are displayed with the data from Meyer et al. (1995) (indicated by the black stars in Figure 5.1). These dates correspond with two periods of fire-related deposition and debris flows in northeast Yellowstone Park. The pulse in frequency of fire-related debris flows at around 900 RCBP corresponds with the Medieval Climatic anomaly (Bradley 1999). This suggests large-scale climate change may be influencing local processes including those processes occurring in mountain environments with a vast array of microenvironmental niches and thus further comparison is not only appropriate but necessary.

The third question asks the following: *Does landscape change occur in patterns in time and space?*

The landscape changes that have occurred within the last 2500 years indicate that the Upper Greybull was influenced by global-scale climatic shifts. Data from Meyer et al. (1995) appear to indicate an increased frequency of fire-related debris flows during the late Holocene. Whitlock's (1993:189) chronology does not extend into the middle and late Holocene but she notes that in the last 1,000-2,000 years vegetation has become more park-like that may be the result of warming trends, more frequent fires, and an increase in bark-beetle infestations arising from both. Mammalian data at Lamar Cave also correspond with the Medieval Climatic Anomaly. These data indicate some regional synchronicity in landscape altering events. It is argued then, that the top down control of climate is influencing landscape change in the Greater Yellowstone Ecosystem.

Patterns of landscape change are also found when combining archaeological site data with landslide data. Two patterns appear: massive slump/flow complexes in the Upper Greybull River study area show stability since the Paleoindian period, though localized surface activity is likely, and smaller flow events and alluvial fans typically do not have occupations until the Late Archaic and Late Prehistoric. Pierce (1968) and Breckenridge (1974) both identify periods massive slope failure after the terminal Pleistocene and relate such events to glacial/pluvial cycles. Reider et al. (1988) also shows late Pleistocene landslides in soil evidence along Dead Indian Pass in the Absaroka Mountains. Water infiltration and increased precipitation are the primary factors in these large mass-wasting events. Evidence of soil formation on the late Pleistocene landslide deposit, observed by Reider et al. (1988) along Dead Indian Pass, indicates a period of relative stability after such events. Soil formation also occurred on a Neoglacial slope or creep deposit along Dead Indian Pass (Reider et al. 1988), suggesting these glacial/pluvial cycles can be catalysts for landslides but the response to these disturbances is soil formation. This is a pattern not unlike the one at 48PA2811.

While landslide events were bigger and less frequent during the Pleistocene, a more recent pattern is one of more frequent, smaller landslide events. The archaeological evidence confirms this theory, indicating a greater diversity in landforms occupied at later time periods which, while this may suggest increased human use of the landscape, also suggests new landforms opening up for use. Possible catalyst for this change in landslide activity includes increased aridity and increased fire.

Why is landscape change important?

Objective 3:

Demonstrate the importance of a methodological framework that incorporates ecological change in archaeological investigations.

The first question under this objective asks: *Why is landscape change important?*

This question focused on why landscape change should be important to archaeological studies. During the Late Holocene time period, people were using the landscape more extensively in the northern Plains, as well as the GYE and Upper Greybull, as shown by the archaeological evidence (Burnett 2005; Frison 1991; Janetski 2002). Based on this study, there also appears to be more frequent, localized disturbance regimes. People may have been attracted to these areas because of the increase in biotic productivity after these events (Romme 1982), and understanding extent of these changes is important to ecological modeling and potential human use of the land. In the broad-spectrum model of mountain environment use by prehistoric occupants, Bender and Wright ask for regional surveys of these areas to identify site type and model potential use of sites. Our understanding of site type and past mountain use will ultimately require researchers to embrace a dynamic ecological perspective to gain contextual information about the environment and site-formation processes. At a very practical level, the knowledge of landscape change aids in identifying areas likely for subsurface archaeological preservation, leading to the recovery of useful data to aid in modeling human use of mountain environments.

The second question was: *How can the archaeological record be incorporated into an "ecology of change" landscape view?*

The theoretical framework for this thesis emphasizes that fact that humans are part of the landscape. Most can agree that humans have influenced the landscape since they have walked the planet, but the impact of hunter and gatherer populations on the landscape has been contested. Lewis (1983:56) explains that the resistance to this idea is based in the assumption that hunters and gatherers are necessarily responsive to local environmental fluctuations and perturbations, not to mention the fact that data on how people changed the landscape is difficult to come by. Archaeological and environmental evidence must be examined together in order to get to the bottom of such questions as: Did human use of fire influence the composition of the Greater Yellowstone Ecosystem? In western Montana, Barrett and Arno (1982) have examined fire scars on old-growth trees within similar forest types, comparing fire intervals near Indian-use zones. Another study in the Bitterroot Mountains of Montana indicates that while marked vegetation change has not occurred in the last 4,000 years, over the last 2,000 years, large concentrations of airborne charcoal occur in lake and bog deposits (Mehringer et al. 1977). Mehringer et al. (1977) see no decrease in effective moisture and see the increase in fires as not easily explained. One possible explanation for the increase in fire in the Bitterroot Mountains is the intentional burning by humans.

Whether humans were burning portions of the GYE is uncertain at this point, but the importance of discussing these possibilities is that the archaeological record can offer a historical perspective to land management. Barrett and Arno (1982) ask the question: What if Indian-caused fires were an important influence on forest succession for centuries or even millennia. Other studies suggest that lightning fires alone may not create or perpetuate certain desirable plant communities or stand conditions and prescribed burning may be needed. Romme's (1982) concluded from his study in Yellowstone National Park that "The use of a carefully planned program of prescribed burning or timber harvesting would undoubtedly make it possible to maintain greater landscape diversity than naturally occurs" (Romme 1982:219). Lewis (1993) also provides ethnographic and ecological data that suggests the coniferous forests in California today are much more susceptible to “holocaust” fires than the park-like forests with uneven-aged stands of the past. Lewis (1993) sees indigenous burning as key to maintaining these forests. Reconstructing fire history and disturbance regimes is useful as a basis for developing ecologically sound fire management and archaeological studies can be incorporated into these policies.

Future directions

The data from this thesis can be integrated into regional synthesis regarding landscape change. However, the chronology of 48PA2811 can be fine-tuned. Radiocarbon dates from PII need to be obtained and compared with the existing data to understand when these surfaces burned but also to better understand what is driving the soil development. Dates from Feature 2 should also be acquired as this occupation was likely one of the last in the 48PA2811 basin. This occupation is also closely related to the modern soil forming layer and will help to date this soil forming period. There is still potential for subsurface preservation north and east of the creek-bank and future exploration will help confirm this and the extent to which the sag pond and depositional events covered this basin. In addition to radiocarbon dates and data recovery, phytoliths analysis of the paleosols will help to answer the question of if vegetation change accompanied the different soil-forming events. This will help to determine if climate change was responsible for the regular forest fires that have occurred in the basin or whether a human catalyst for such events is arguable. There are more sag ponds throughout the Upper Greybull and plenty of opportunity for future researches to acquire environmental and archaeological data from these locations. An eventual synthesis of landscape data from different locales in the Upper Greybull may help in developing a regional fire chronology and could identify region-wide soil forming events.

There are many possibilities for using the landslide data in the Upper Greybull to gain a better sense of regional synchronicity of such events and their effect of the archaeological record. Glacial-related events are one possibility. Alluvial fan formations are another avenue, especially because of their high probability in producing sub-surface buried cultural materials. Archaeological associations with these landforms can provide some idea of timing for events but only absolute dating will lead to a chronology of landscape change for the region to be compared with similar processes occurring throughout the Greater Yellowstone Ecosystem and the Northern Plains.

Any future study needs to reach across disciplines to address questions about landscape change in mountain environments to reach the more interesting questions not just about human use of these landscapes but the possible human impact on these landscapes.

Conclusion

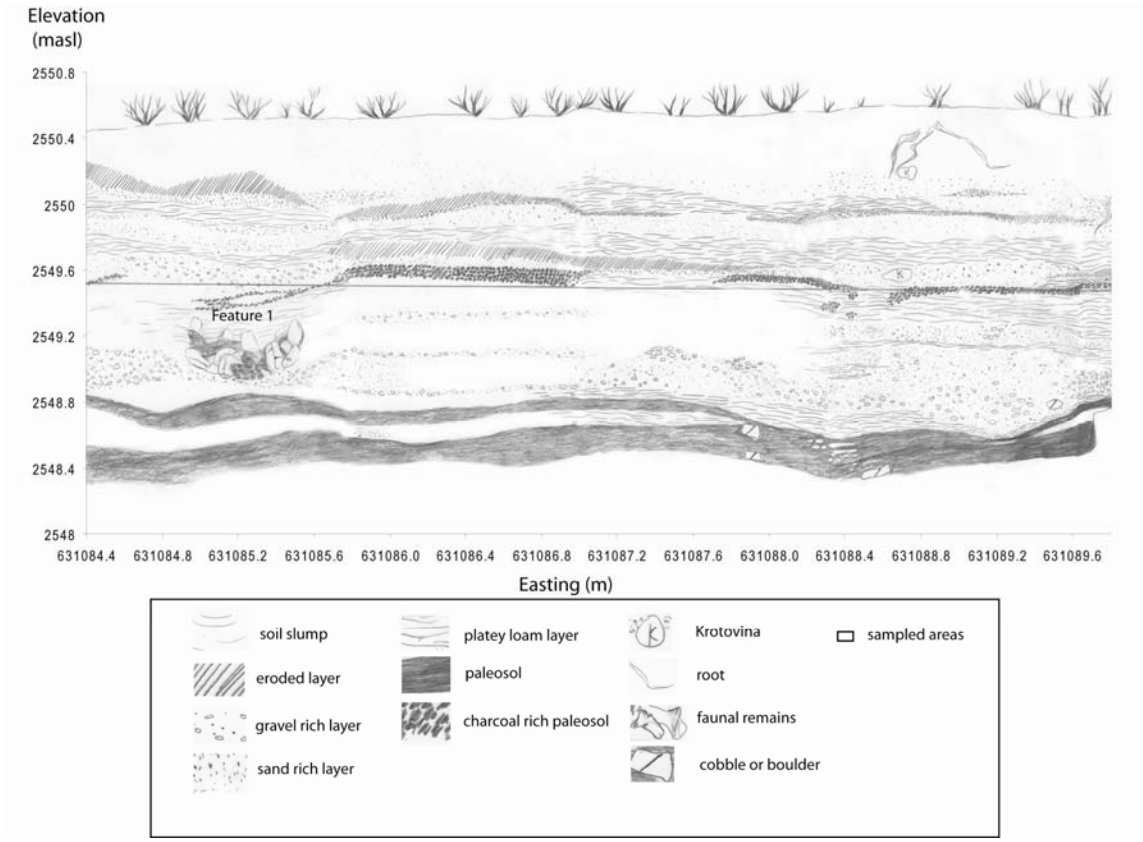
The Upper Greybull River contains an archaeological record spanning from the Late Paleoindian to historic times. These archaeological sites are part of a dynamic landscape. This thesis has demonstrated that a detailed account of landscape change can be constructed from the Late Archaic period to present based on site 48PA2811. While extensive change in the form of landslides, glacial/pluvial cycles, and forest belt shifts, just to name a few, have occurred throughout the Upper Greybull through time, the Late

Archaic and onward was a very active period. The Late Archaic saw an increase in cultural activity, fire activity, and landslide activity. While it is uncertain whether the fires occurring are a result of climate fluctuations or human management in the region, it is clear that these disturbance regimes are part of a cycle that defines this subalpine landscape. By incorporating the archaeological record into a landscape history, more can be discovered about natural processes and the relationships between geology, biology and climate.

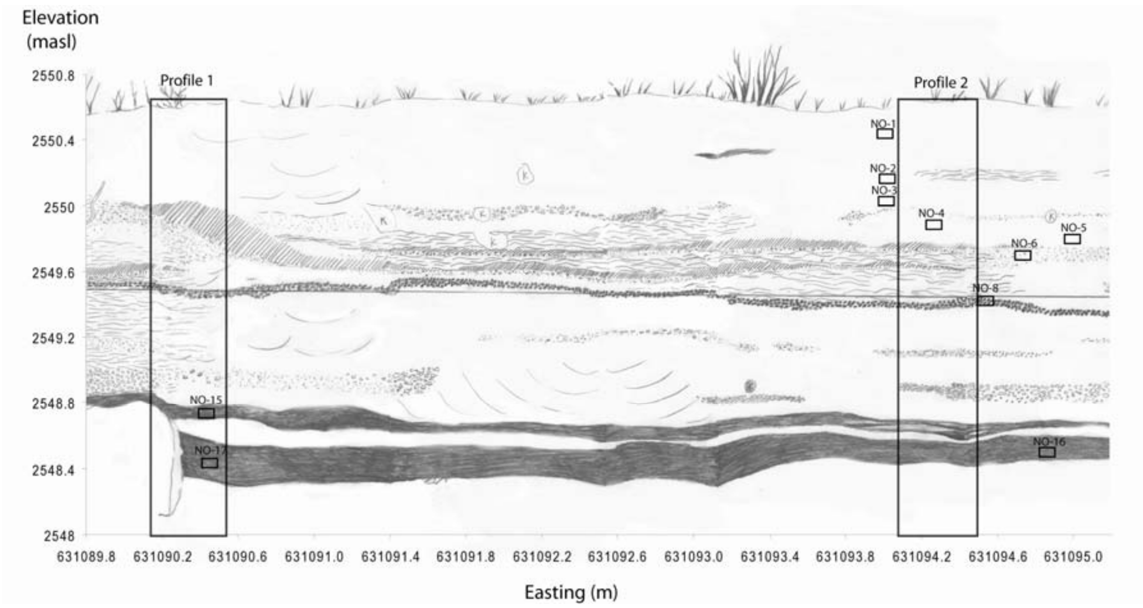
Appendix A
Artifact Code Sheet

Category	Description		
EAST83	Easting UTM (Universal Transverse Mercator) coordinate	BLL1	Blade length 1
NORTH83	Northing UTM (Universal Transverse Mercator) coordinate	BLL2	Blade length 2
ELEVATION	Elevation in meters above sea level	ND1	Notch depth 1
INI	Initial of data collector	ND2	Notch depth 2
WAYPOINT	Waypoint name or number on GPS unit	ND3	Notch depth 3
DATE	Waypoint date	NW	Neck or haft width
SITE	Temporary site number or isolated find	NH	Neck or haft height
SURVEY	Sampling method	BH	Base height-from proximal to widest point on base
GPS COMMENTS	Additional comments entered in GPS	BW	Base width
IPAQ	Name of iPAQ	TIME	Time period of association
SUBPT	Modified-Whittaker plot or subplot		
FLG	color of flag during transect		
DOT	Presence of a marker dot on the artifact (from prev. recording)		
UP	Side of artifact facing skyward		
CON	Micro-scale environmental context of artifacts		
CL	Artifact class or category--most general description		
EL	Artifact element or type		
POR	Artifact portion or completeness		
MAT	Artifact material type		
CLR1	Dominant color		
CLR2	Second dominant color		
INCL	Inclusion color		
HT	Heat modifications		
C/T	Clast or technological measurements?		
MLEN	Maximum length (mm)		
MWID	Maximum width (mm)		
MTHK	Maximum thickness (mm)		
PTW	Platform width (mm)		
PTT	Platform thickness (mm)		
SCR	Scar count		
CTX	Cortex values		
COMMENTS	Additional artifact comments		
PHOTO1	Photo number		
PHOTO2	Photo number		
PHOTO3	Photo number		
AXLEN	Axial or midline length		

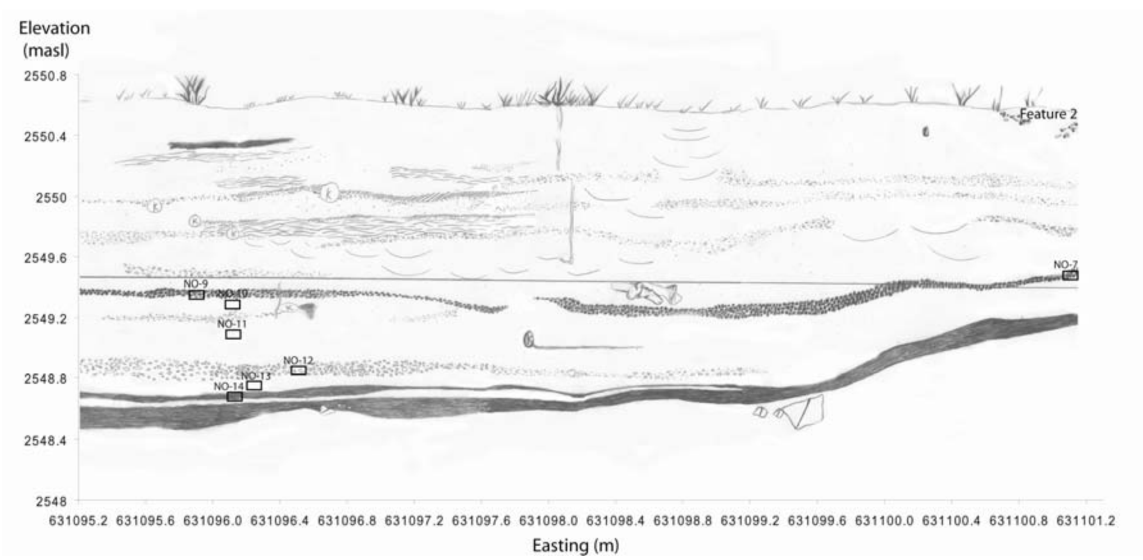
Appendix B
Profile Map of Piney Creek Exposure



Profile section 1



Profile section 2



Profile section 3

Appendix C
Samples Collected

Sediments collected from hearth feature 1

Number	Location collected from	Description
SDSP001	bottom hearth	Charcoal laden
SDSP002	bottom hearth	Charcoal laden
SDSP003	between top of hearth and burn line	
SDSP004	behind log 1 under rocks	hearth fill
SDSP005	under rocks center of hearth	hearth fill
SDSP006	east/central hearth	hearth fill
SDSP007	west edge below rock 14	hearth fill
SDSP008	above rocks includes burn layer	
SDSP009	central bottom	hearth fill
SDSP010	central hearth under rocks	

Charcoal collected from hearth feature 1

Number	Location collected from
CHSP001	
CHSP002	outer log 1 sample
CHSP003	inner log 1 sample
CHSP004	generic log 1 sample
CHSP005	log 2 bulk sample

Soils and sediments collected

Field #	Laboratory #	Date collected	Depth from surface (cm)	Profile	Stratigraphic association	Color dry	moist	Structure
SDSP119	NO-36	2006-09-27	4	1	modern A horizon	10YR3/3	10YR2/2	1cogr
SDSP109	NO-26	2006-09-27	115	1	above burn layer	10YR4/2	10YR3/2	2cosbk
SDSP108	NO-25	2006-09-27	123	1	burn layer	10YR3/1	10YR2/1	2cosbk
SDSP107	NO-24	2006-09-27	130	1	below burn layer	10YR5/2	10YR4/2	2vkpl
SDSP106	NO-23	2006-09-27	181	1	above PII	10YR4/2	10YR2/2	2tkpl
SDSP105	NO-22	2006-09-27	191	1	center PII	10YR4/1	10YR2/1	2copr
SDSP104	NO-21	2006-09-27	197	1	below PII	10YR5/2	10YR3/2	sg
SDSP102	NO-19	2006-09-27	209	1	center PIII	10YR3/1	10YR2/1	3copr
SDSP100	NO-18	2006-09-27	231	1	below PIII	10YR4/3	10YR3/3	3cosbk
SDSP118	NO-35	2006-09-27	4	2	modern A horizon	10YR4/2	10YR2/2	1cogr
SDSP117	NO-34	2006-09-27	110	2	above burn layer	10YR4/2	10YR3/2	2vkpl
SDSP116	NO-33	2006-09-27	116	2	burn layer	10YR2/1	10YR2/1	2cosbk
SDSP115	NO-32	2006-09-27	124	2	below burn layer	10YR5/2	10YR4/2	2tkpl
SDSP114	NO-31	2006-09-27	168	2	above PII	10YR4/2	10YR3/2	2tkpl
SDSP113	NO-30	2006-09-27	176	2	center PII	10YR3/2	10YR2/2	2copr
SDSP112	NO-29	2006-09-27	180	2	above PIII	10YR4/2	10YR3/2	2cosbk
SDSP111	NO-28	2006-09-27	192	2	center PIII	10YR3/1	10YR2/1	3copr
SDSP110	NO-27	2006-09-27	208	2	below PIII	10YR4/2	10YR3/2	3cosbk
SDSPNO38	NO-1	2005-06-02	14	bulk	B horizon	10YR4/2	10YR2/2	2copr
SDSPNO36	NO-2	2005-06-02	48	bulk		10YR5/2	10YR4/2	3vcpr
SDSPNO35	NO-3	2005-06-02	52	bulk	krotovina?	10YR5/2	10YR4/2	2vkpl
SDSPNO34	NO-4	2005-06-02	62	bulk		10YR5/2	10YR4/2	3vcpr
SDSPNO33	NO-5	2005-06-02	68	bulk		10YR5/2	10YR4/2	2tkpl
SDSPNO32	NO-6	2005-06-02	82	bulk		10YR5/2	10YR4/2	sg
SDSPNO31	NO-8	2005-06-02	102	bulk	above burn layer	10YR5/2	10YR3/2	2vkpl
SDSPNO30	NO-9	2005-06-02	114	bulk	charcoal layer	10YR4/1	10YR3/1	2cosbk
SDSPNO29	NO-10	2005-06-02	118	bulk	below charcoal layer	10YR5/2	10YR4/2	sg
SDSPNO28	NO-11	2005-06-02	138	bulk		10YR5/2	10YR4/2	2copr
SDSPNO27	NO-12	2005-06-02	158	bulk	coarse sand/gravel layer	10YR5/2	10YR3/2	sg
SDSPNO26	NO-13	2005-06-02	164	bulk	darker layer above PII	10YR5/2	10YR3/2	2tkpl
SDSPNO25	NO-14	2005-06-02	170	bulk	PII	10YR4/1	10YR2/2	
SDSPNO39	NO-15	2005-06-02	172	bulk	PII	10YR4/1	10YR3/1	2copr
SDSPNO24	NO-16	2005-06-02	192	bulk	PIII	10YR3/1	10YR2/1	
SDSPNO23	NO-17	2005-06-02	198	bulk	PIII	10YR3/1	10YR2/1	3copr
SDSPNO37	NO-7	2005-06-02	110	bulk	burn layer	10YR4/1	10YR2/1	1vkpl

Appendix D

Texture Data

sample #	Wt. plastic bottle +cap	Wt. sample	wt sodium hexametaph. (control) (~50 g)	hydrom (control)	Temp (control)	40 sec hydro read #1	40 sec hydro read #2	Temp read for #2	Ave hydro read for #1 and #2	2 hr hydro read	2 hr temp read	adj control	adj 40 sec ave	adj 2hr
NO1-1	32.6790	49.2460	49.9540	4	26	16	16	28	16	12	26	6.16	18.88	14.16
NO2-1	32.4360	47.9860	49.9540	4	26	17	17	27	17	12	26	6.16	19.52	14.16
NO3-1	32.4730	50.0490	49.9540	4	26	24	25	27	24.5	14	26	6.16	27.02	16.16
NO4-1	32.4200	48.9290	49.9540	4	26	15	15	28	15	11	26	6.16	17.88	13.16
NO5-1	32.4430	50.4630	49.9540	4	26	29	31	27	30	14	26	6.16	32.52	16.16
NO6-1	32.4030	48.2350	49.9540	4	26	7	7	28	7	7	26	6.16	9.88	9.16
NO7-1	32.5640	50.0240	49.9540	4	26	16	18	28	17	13	26	6.16	19.88	15.16
NO8-1	22.1645	28.7185	49.9540	4	26	19	20	28	19.5	10	26	6.16	22.38	12.16
NO9-1	19.7080	31.1530	49.9540	4	26	21	21	28	21	13	26	6.16	23.88	15.16
NO10-1	32.6490	50.0770	50.1460	5	25	13	13	26	13	8	25	6.8	15.16	9.8
NO11-1	32.3390	50.4510	50.1460	5	25	25	26	26	25.5	13	25	6.8	27.66	14.8
NO12-1	32.4960	50.2460	50.1460	5	25	9	10	26	9.5	7	25	6.8	11.66	8.8
NO13-1	32.6130	49.3750	50.1460	5	25	20	21	25	20.5	12	25	6.8	22.3	13.8
NO14-1	32.3300	49.8320	50.1460	5	25	21	21	26	21	13	25	6.8	23.16	14.8
NO15-1	32.3730	49.9270	50.1460	5	25	28	27	26	27.5	16	25	6.8	29.66	17.8
NO16-1	22.1550	30.1240	50.1460	5	25	15	16	26	15.5	7	25	6.8	17.66	8.8
NO17-1	21.8490	29.5010	50.1460	5	25	18	18	26	18	12	25	6.8	20.16	13.8
NO18-1	32.3160	50.3100	49.9986	6	23	22	22	26	22	13	25	7.08	24.16	14.8
NO19-1	32.3490	49.9050	49.9986	6	24	15	16	25	15.5	8	25	7.44	17.3	9.8
NO20-1	32.6510	50.2840	49.9986	6	24	25	25	26	25	12	25	7.44	27.16	13.8
NO21-1	32.4980	49.6360	49.9986	6	24	13	12	25	12.5	10	25	7.44	14.3	11.8
NO22-1	32.3600	49.9270	49.9986	6	24	25	25	25	25	12	25	7.44	26.8	13.8
NO23-1	32.5860	49.2950	49.9986	6	23	23	22	26	22.5	14	25	7.08	24.66	15.8
NO24-1	32.3890	50.0710	49.9986	6	23	26	27	25	26.5	15	25	7.08	28.3	16.8
NO25-1	32.4540	50.5030	49.9986	6	24	31	31	25	31	15	25	7.44	32.8	16.8
NO26-1	32.5160	49.5110	49.9986	6	22	36	35	23	35.5	18	24	6.72	36.58	19.44
NO27-1	32.5170	49.1550	49.9986	6	22	23	22	23	22.5	15	23	6.72	23.58	16.08
NO28-1	32.2580	50.0290	49.9986	6	23	25	25	25	25	14	25	7.08	26.8	15.8
NO29-1	32.5460	49.5520	49.9986	6	23	16	16	25	16	11	25	7.08	17.8	12.8
NO30-1	32.5930	49.6260	49.9986	6	23	29	29	26	29	11	25	7.08	31.16	12.8
NO31-1	19.4280	25.3130	49.9986	6	22	12	12	24	12	8	24	6.72	13.44	9.44
NO32-1	22.1310	24.8700	49.9986	6	22	19	19	23	19	11	24	6.72	20.08	12.44
NO33-1	21.8270	24.7350	49.9986	6	23	20	20	25	20	11	24	7.08	21.8	12.44
NO34-1	19.2640	25.5710	49.9986	6	23	14	16	24	15	10	24	7.08	16.44	11.44
NO35-1	19.6960	24.3910	49.9986	6	23	14	13	24	13.5	8	23	7.08	14.94	9.08
NO36-1	19.5390	25.2750	49.9986	6	22	13	14	24	13.5	9	24	6.72	14.94	10.44

corrected 40 sec	corrected 2 hr	%silt+ %clay	%clay	%silt	%sand	
12.72	8	25.8295	16.245	9.585	74.1705	sandy loam
13.36	8	27.8415	16.672	11.17	72.1585	sandy loam
20.86	10	41.6792	19.98	21.7	58.3208	sandy loam
11.72	7	23.9531	14.306	9.647	76.0469	sandy loam
26.36	10	52.2363	19.816	32.42	47.7637	loam
3.72	3	7.71224	6.2196	1.493	92.2878	sand
13.72	9	27.4268	17.991	9.435	72.5732	sandy loam
16.22	6	56.4793	20.892	35.59	43.5207	loam
17.72	9	56.8806	28.89	27.99	43.1194	clay loam
8.36	3	16.6943	5.9908	10.7	83.3057	loamy sand
20.86	8	41.347	15.857	25.49	58.653	sandy loam
4.86	2	9.67241	3.9804	5.692	90.3276	sand
15.5	7	31.3924	14.177	17.22	68.6076	sandy loam
16.36	8	32.8303	16.054	16.78	67.1697	sandy loam
22.86	11	45.7868	22.032	23.75	54.2132	sandy clay loam
10.86	2	36.051	6.6392	29.41	63.949	sandy loam
13.36	7	45.2866	23.728	21.56	54.7134	sandy clay loam
17.08	7.72	33.9495	15.345	18.6	66.0505	sandy loam
9.86	2.36	19.7575	4.729	15.03	80.2425	loamy sand
19.72	6.36	39.2172	12.648	26.57	60.7828	sandy loam
6.86	4.36	13.8206	8.7839	5.037	86.1794	sand
19.36	6.36	38.7766	12.739	26.04	61.2234	sandy loam
17.58	8.72	35.6628	17.689	17.97	64.3372	sandy loam
21.22	9.72	42.3798	19.412	22.97	57.6202	sandy loam
25.36	9.36	50.2148	18.534	31.68	49.7852	loam
29.86	12.72	60.3098	25.691	34.62	39.6902	loam
16.86	9.36	34.2997	19.042	15.26	65.7003	sandy loam
19.72	8.72	39.4171	17.43	21.99	60.5829	sandy loam
10.72	5.72	21.6338	11.543	10.09	78.3662	sandy loam
24.08	5.72	48.523	11.526	37	51.477	loam
6.72	2.72	26.5476	10.745	15.8	73.4524	sandy loam
13.36	5.72	53.7193	23	30.72	46.2807	loam
14.72	5.36	59.5108	21.67	37.84	40.4892	loam
9.36	4.36	36.604	17.051	19.55	63.396	sandy loam
7.86	2	32.225	8.1997	24.03	67.775	sandy loam
8.22	3.72	32.5223	14.718	17.8	67.4777	sandy loam

Calculations:

1) Adjusted Hydrometer Readings

a. If the temperature was above 20C then add .36 g/L for each degree above 20C

b. If the temperature was below 20C then subtract .36g/L for each degree below 20C

2) Corrected Hydrometer Readings

a. Subtract adjusted control reading from adjusted (ave) 40 sec reading

b. Subtract adjusted control reading from adjusted 2 hour reading

3) Calculate % sand, silt, and clay

a. %sand + %silt + %clay=100%

b. %silt + %clay=[(corrected 40 sec reading in gm/L) *100]/weight of fine fraction

c. %clay=[(corrected 2 hour reading in gm/L) *100]/weight of fine fraction

Appendix E
Inorganic Carbon Data and Calculations

Inorganic carbon blanks		
sample	voltage	
blank 1	0.09	
blank 2	0.07	
blank 3	0.08	average
		0.08

standards for regression sample %CaCO3	weight (g)	volts (V)	X-axis blank corr.volts (volts-average blank volts)	Y-axis inorganic carbon (g) ((%CaCO3*.0012)weight)
0.25	1.0438	0.19	0.11	0.00031314
0.5	1.0591	0.23	0.15	0.00063546
1	1.0336	0.39	0.31	0.00124032
2	1.0414	0.70	0.62	0.00249936
3	1.0427	0.93	0.85	0.00375372
5	1.0409	1.52	1.44	0.0062454

Regression output	
Intercept (b)	-1.22E-04
Slope (m)	0.00443163
R squared	0.999224

sample	weight (g)	volts (V)	blank corr.volts (volts-average blank volts)	inorganic carbon gC/g soil (b+(blank corr.volts*m)/weight)	%inorganic carbon (inorganic carbon*100)	
NO1	0.9703	0.15	0.07	0.0001935	0.0193516	
NO2	1.0078	0.14	0.06	0.0001423	0.0142342	
NO3	0.9842	0.13	0.05	0.0001007	0.0100727	
NO4	1.0302	0.13	0.05	0.0000962	0.0096229	
NO5	0.9996	0.14	0.06	0.0001435	0.0143509	
NO6	0.9974	0.12	0.04	0.0000550	0.0054962	
NO7	1.0258	0.13	0.05	0.0000966	0.0096642	
NO8	0.9968	0.15	0.07	0.0001884	0.0188371	
NO9	1.0200	0.17	0.09	0.0002710	0.0270981	
NO10	1.0070	0.14	0.06	0.0001425	0.0142455	
NO11	0.9958	0.09	0.01	-0.0000785	-0.0078459	Redo
NO12	1.0215	0.13	0.05	0.0000970	0.0097049	
NO13	1.0017	0.13	0.05	0.0000990	0.0098967	
NO14	1.0051	0.15	0.07	0.0001868	0.0186815	
NO15	1.0333	0.14	0.06	0.0001388	0.0138829	
NO16	1.0031	0.06	-0.02	-0.0002104	-0.0210426	Redo
NO17	1.0235	0.15	0.07	0.0001835	0.0183457	
NO18	1.0267	0.14	0.06	0.0001397	0.0139721	
NO19	1.0145	0.14	0.06	0.0001414	0.0141401	
NO20	0.9918	0.14	0.06	0.0001446	0.0144638	
NO21	0.9912	0.12	0.04	0.0000553	0.0055306	
NO22	0.9718	0.11	0.03	0.0000108	0.0010808	
NO23	0.9915	0.11	0.03	0.0000106	0.0010593	
NO24	0.9834	0.13	0.05	0.0001008	0.0100809	

NO25	1.0450	0.12	0.04	0.0000525	0.0052459
NO26	1.0022	0.14	0.06	0.0001431	0.0143137
NO27	1.0215	0.14	0.06	0.0001404	0.0140432
NO28	1.0086	0.11	0.03	0.0000104	0.0010413
NO29	1.0069	0.12	0.04	0.0000544	0.0054443
NO30	0.9697	0.11	0.03	0.0000108	0.0010831
NO31	1.0334	0.13	0.05	0.0000959	0.0095931
NO32	0.9965	0.13	0.05	0.0000995	0.0099484
NO33	1.0194	0.14	0.06	0.0001407	0.0140722
NO34	0.9696	0.13	0.05	0.0001022	0.0102244
NO35	0.9741	0.14	0.06	0.0001473	0.0147266
NO36	1.0198	0.12	0.04	0.0000538	0.0053755

blanks

sample	voltage	
blank 1	0.12	
blank 2	0.11	
blank 3	0.11	average
		0.11

standards

sample %CaCO3	weight (g)	volts (V)	X-axis blank corr.volts	Y-axis inorganic carbon (g)	Regression output	
0.25	1.003	0.15	0.04	0.0003009	Intercept (b)	-3.33E-05
0.5	1.0287	0.27	0.16	0.00061722	Slope (m)	0.004508
1	1.0187	0.40	0.29	0.00122244	R squared	0.9978174
2	1.0205	0.67	0.56	0.0024492		
3	1.0296	0.99	0.88	0.00370656		
5	1.0108	1.43	1.32	0.0060648		

sample	weight (g)	volts (V)	blank corr.volts	inorganic carbon	%inorganic
NO11	1.0055	0.15	0.04	0.000131287	0.013128699
NO16	0.9965	0.13	0.02	4.19962E-05	0.004199616

Appendix F
All Soil Laboratory Results

Bulk samples

sample	cm below surface	%inorganic carbon	%nitrogen	%total carbon	%organic carbon	δ13C	pH	%silt&clay	%clay	%silt	%sand	clayfree index	C:N
NO35	4	0.014727	0.1476	1.663	1.648273	-25.156	7.5	32.2250	8.1997	24.0253	67.7750	1.3545	11.2669
NO1	14	0.019352	0.0877	0.798	0.778648	-23.687	7.1	25.8295	16.2450	9.5845	74.1705	1.1292	9.0992
NO2	48	0.014234	0.0417	0.4269	0.412666	-23.834	7.3	27.8415	16.6715	11.1699	72.1586	1.1548	10.2374
NO3	52	0.010073	0.0873	0.8105	0.800427	-23.888	6.9	41.6792	19.9804	21.6987	58.3209	1.3721	9.2841
NO4	62	0.009623	0.0369	0.334	0.324377	-23.733	7.7	23.9531	14.3064	9.6466	76.0469	1.1269	9.0515
NO5	68	0.014351	0.0845	0.9734	0.959049	-23.999	7.6	52.2363	19.8165	32.4198	47.7637	1.6788	11.5195
NO6	82	0.005496	0.0109	0.2147	0.209204	-23.965	8	7.7122	6.2196	1.4927	92.2878	1.0162	19.6972
NO8	102	0.018837	0.1114	1.232	1.213163	-23.993	7.9	56.4793	20.8925	35.5868	43.5207	1.8177	11.0592
NO7	110	0.009664	0.1245	2.431	2.421336	-24.383	7.8	27.4268	17.9914	9.4355	72.5732	1.1300	19.5261
NO9	114	0.027098	0.1892	3.003	2.975902	-24.65	7.8	56.8806	28.8897	27.9909	43.1194	1.6491	15.8721
NO10	118	0.014245	0.0399	0.4557	0.441455	-23.669	8.3	16.6943	5.9908	10.7035	83.3057	1.1285	11.4211
NO11	138	0.013129	0.0608	0.6457	0.632571	-23.814	8	41.3471	15.8570	25.4901	58.6530	1.4346	10.6201
NO12	158	0.009705	0.017	0.2396	0.229895	-23.603	8	9.6724	3.9804	5.6920	90.3276	1.0630	14.0941
NO13	164	0.009897	0.066	0.8068	0.796903	-23.782	7.6	31.3924	14.1772	17.2152	68.6076	1.2509	12.2242
NO14	170	0.018682	0.0964	1.179	1.160318	-24.156	7.3	32.8303	16.0539	16.7764	67.1697	1.2498	12.2303
NO15	172	0.013883	0.1581	2.078	2.064117	-23.148	7	45.7869	22.0322	23.7547	54.2132	1.4382	13.1436
NO29	180	0.005444	0.0459	0.4593	0.453856	-23.654	7.3	21.6338	11.5434	10.0904	78.3662	1.1288	10.0065
NO16	192	0.0042	0.2274	2.631	2.6268	-24.104	6.7	36.0510	6.6392	29.4118	63.9490	1.4599	11.5699
NO17	198	0.018346	0.2358	2.653	2.634654	-24.007	6.8	45.2866	23.7280	21.5586	54.7134	1.3940	11.2511

Profile 1

sample	cm below surface	%inorganic carbon	%nitrogen	%total carbon	%organic carbon	δ13C	pH	%silt&clay	%clay	%silt	%sand	clayfree index	C:N
NO36	4	0.005375	0.1188	1.422	1.416625	-24.837	7.3	32.5223	14.7181	17.8042	67.4777	1.2639	11.9697
NO26	115	0.014314	0.1475	1.838	1.823686	-24.311	7.7	60.3098	25.6913	34.6186	39.6902	1.8722	12.4610
NO25	123	0.005246	0.1971	3.056	3.050754	-24.101	7.9	50.2148	18.5336	31.6813	49.7852	1.6364	15.5048
NO24	130	0.010081	0.033	0.4307	0.420619	-23.743	8	42.3798	19.4124	22.9674	57.6202	1.3986	13.0515
NO23	181	0.001059	0.1052	1.124	1.122941	-24.112	7.5	35.6629	17.6894	17.9734	64.3372	1.2794	10.6844
NO22	191	0.001081	0.14	1.768	1.766919	-23.961	7.2	38.7766	12.7386	26.0380	61.2234	1.4253	12.6286
NO21	197	0.005531	0.0356	0.3915	0.385969	-23.072	7.5	13.8206	8.7839	5.0367	86.1794	1.0584	10.9972
NO19	209	0.01414	0.3516	4.924	4.90986	-24.219	6.8	19.7575	4.7290	15.0286	80.2425	1.1873	14.0046
NO18	231	0.013972	0.0491	0.5408	0.526828	-23.332	6.8	33.9495	15.3449	18.6047	66.0505	1.2817	11.0143

Profile 2

sample	cm below surface	%inorganic carbon	%nitrogen	%total carbon	%organic carbon	δ13C	pH	%silt&clay	%clay	%silt	%sand	clayfree index	C:N
NO35	4	0.014727	0.1476	1.663	1.648273	-25.156	7.5	32.2250	8.1997	24.0253	67.7750	1.3545	11.2669
NO34	110	0.010224	0.0632	0.9669	0.956676	-24.27	8.4	36.6040	17.0506	19.5534	63.3960	1.3084	15.2991
NO33	116	0.014072	0.1975	3.242	3.227928	-24.603	8.1	59.5108	21.6697	37.8411	40.4892	1.9346	16.4152
NO32	124	0.009948	0.0465	0.5089	0.498952	-23.723	8.1	53.7193	22.9996	30.7197	46.2807	1.6638	10.9441
NO31	168	0.009593	0.0795	0.8842	0.874607	-24.077	7.4	26.5476	10.7455	15.8022	73.4524	1.2151	11.1220
NO30	176	0.001083	0.1483	1.982	1.980917	-24.245	7.2	48.5230	11.5262	36.9967	51.4771	1.7187	13.3648
NO29	180	0.005444	0.0459	0.4593	0.453856	-23.654	7.3	21.6338	11.5434	10.0904	78.3662	1.1288	10.0065
NO28	192	0.001041	0.2361	3.192	3.190959	-24.278	6.9	39.4171	17.4299	21.9873	60.5829	1.3629	13.5197
NO27	208	0.014043	0.059	0.5842	0.570157	-23.323	6.9	34.2997	19.0418	15.2579	65.7003	1.2322	9.9017

Appendix G

Radiocarbon Laboratory Data and Calibration Data

Colorado State University — Material Received: 6/23/2005

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 206176	1560 +/- 90 BP	-25.6 o/oo	1550 +/- 90 BP

SAMPLE : 2811-1I
ANALYSIS : Radiometric-Standard delivery (with extended counting)
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 330 to 660 (Cal BP 1620 to 1290)

Beta - 206177	1110 +/- 60 BP	-25.7 o/oo	1100 +/- 60 BP

SAMPLE : 2811-1O
ANALYSIS : Radiometric-Standard delivery (with extended counting)
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 790 to 1030 (Cal BP 1160 to 920)

Beta - 206178	1050 +/- 60 BP	-25.6 o/oo	1040 +/- 60 BP

SAMPLE : 2811-2
ANALYSIS : Radiometric-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 890 to 1060 (Cal BP 1060 to 890) AND Cal AD 1080 to 1150 (Cal BP 860 to 800)

Material Received: 10/9/2006

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 222039 SAMPLE : 48PA2811RC1 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 840 to 770 (Cal BP 2790 to 2720)	2610 +/- 50 BP	-24.2 o/oo	2620 +/- 50 BP
Beta - 222040 SAMPLE : 48PA2811RC3 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1000 to 1170 (Cal BP 950 to 780)	1000 +/- 40 BP	-27.0 o/oo	970 +/- 40 BP
Beta - 222041 SAMPLE : 48PA2811RC4 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 790 to 410 (Cal BP 2740 to 2360)	2520 +/- 40 BP	-27.4 o/oo	2480 +/- 40 BP
Beta - 222042 SAMPLE : 48PA2811RC6 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1030 to 1250 (Cal BP 920 to 700)	900 +/- 40 BP	-26.2 o/oo	880 +/- 40 BP

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.6:lab. mult=1)

Laboratory number: **Beta-206176**

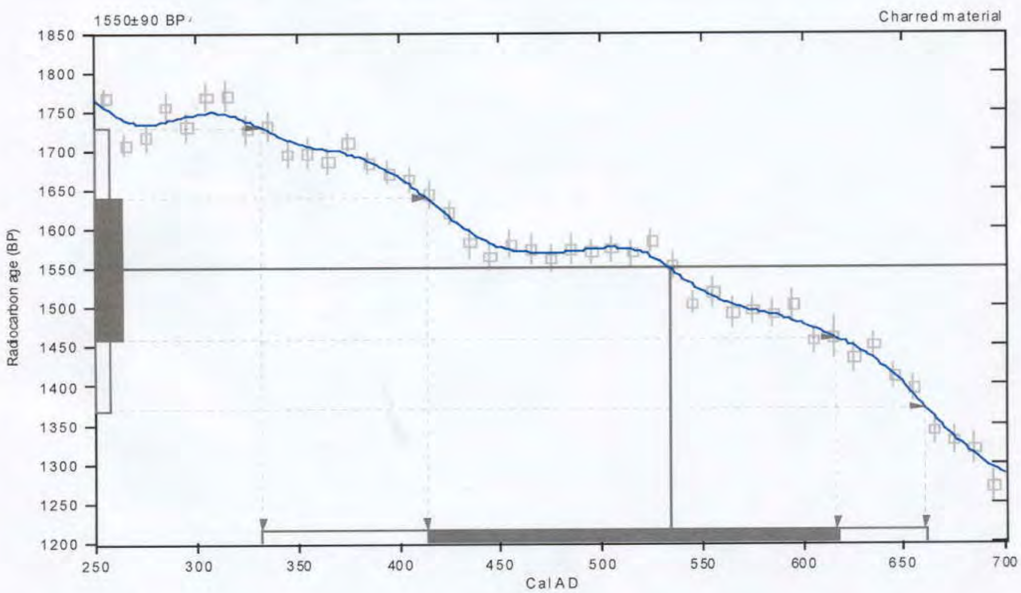
Conventional radiocarbon age: **1550±90 BP**

2 Sigma calibrated result: (95% probability) **Cal AD 330 to 660 (Cal BP 1620 to 1290)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 530 (Cal BP 1420)

1 Sigma calibrated result: (68% probability) Cal AD 410 to 620 (Cal BP 1540 to 1330)



References:

Database used

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Calibration Database

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INTCAL98 Radiocarbon Age Calibration

Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083

Mathematics

A Simplified Approach to Calibrating C14 Dates

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

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.7:lab. mult=1)

Laboratory number: **Beta-206177**

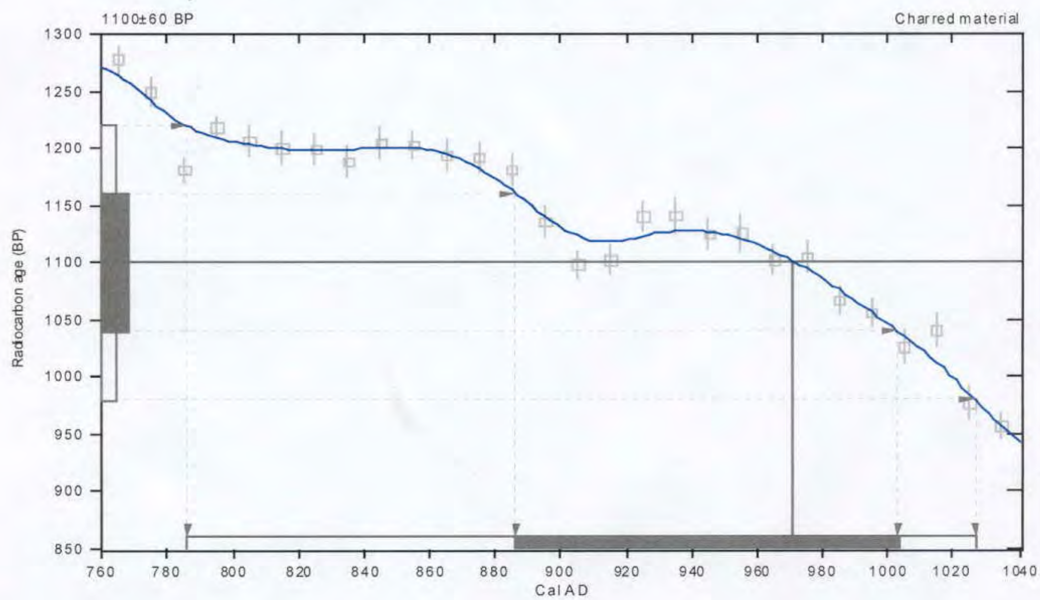
Conventional radiocarbon age: **1100±60 BP**

2 Sigma calibrated result: (95% probability) **Cal AD 790 to 1030 (Cal BP 1160 to 920)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 970 (Cal BP 980)

1 Sigma calibrated result: (68% probability) Cal AD 890 to 1000 (Cal BP 1060 to 950)



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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24.2:lab. mult=1)

Laboratory number: **Beta-222039**

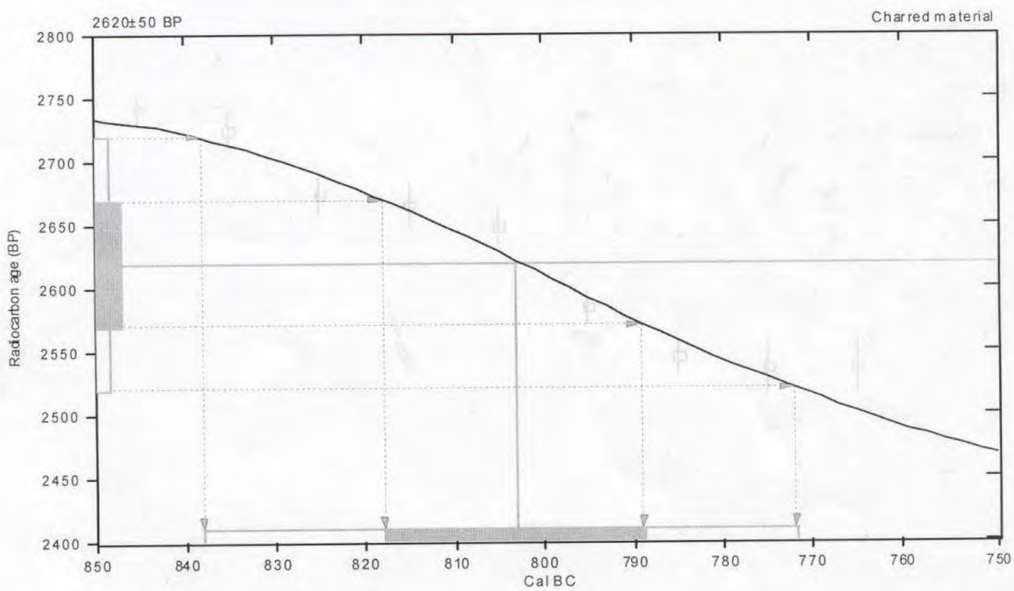
Conventional radiocarbon age: **2620±50 BP**

2 Sigma calibrated result: **Cal BC 840 to 770 (Cal BP 2790 to 2720)**
(95% probability)

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 800 (Cal BP 2750)

1 Sigma calibrated result: Cal BC 820 to 790 (Cal BP 2770 to 2740)
(68% probability)



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Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.6:lab. mult=1)

Laboratory number: **Beta-206178**

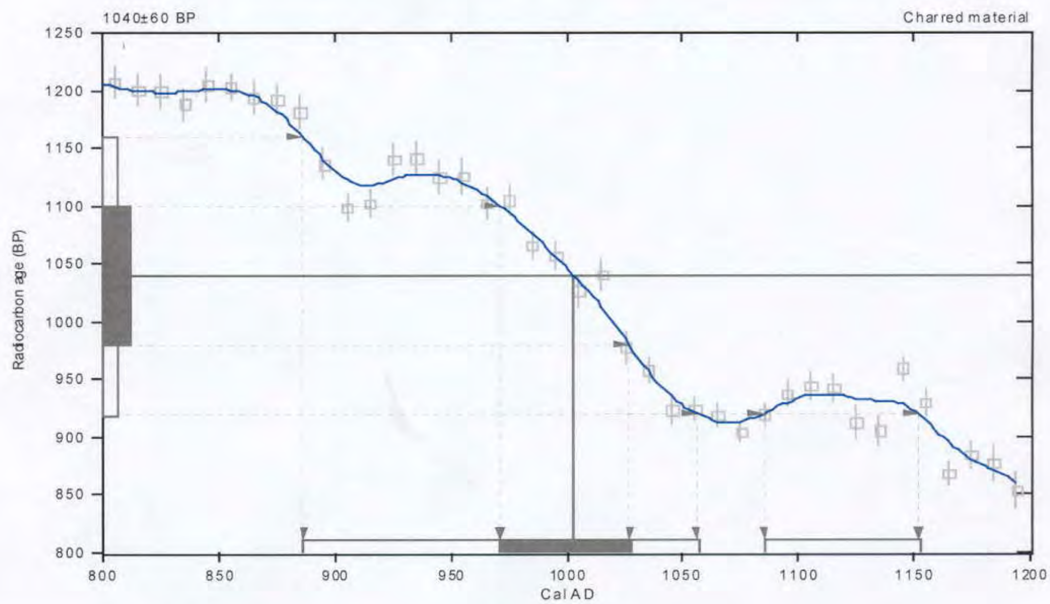
Conventional radiocarbon age: **1040±60 BP**

2 Sigma calibrated results: **Cal AD 890 to 1060 (Cal BP 1060 to 890) and**
(95% probability) **Cal AD 1080 to 1150 (Cal BP 860 to 800)**

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 1000 (Cal BP 950)

1 Sigma calibrated result: Cal AD 970 to 1030 (Cal BP 980 to 920)
(68% probability)



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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-27:lab. mult=1)

Laboratory number: **Beta-222040**

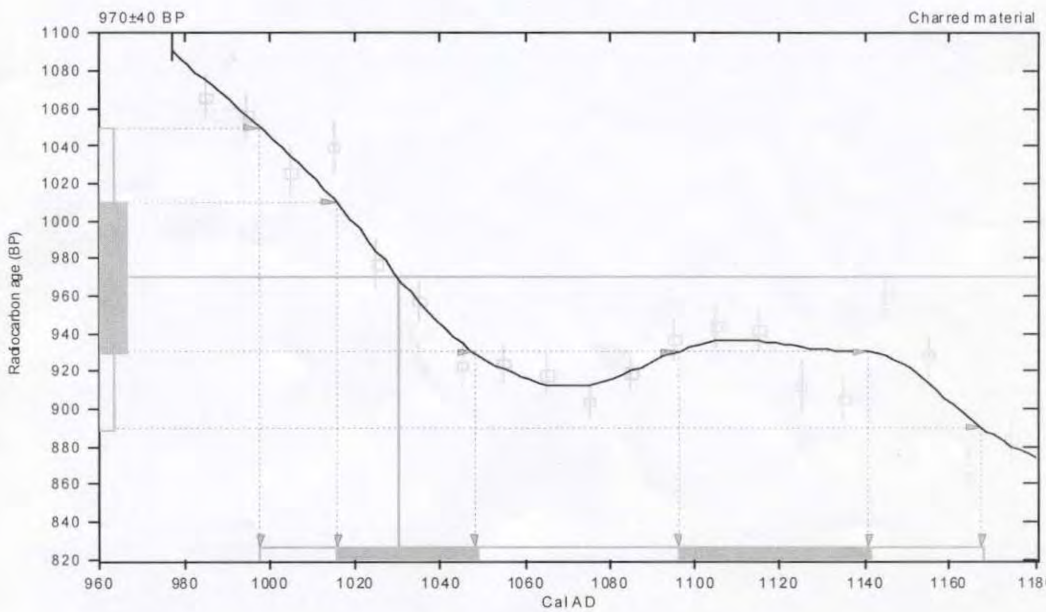
Conventional radiocarbon age: **970±40 BP**

2 Sigma calibrated result: (95% probability) **Cal AD 1000 to 1170 (Cal BP 950 to 780)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 1030 (Cal BP 920)

1 Sigma calibrated results: (68% probability) Cal AD 1020 to 1050 (Cal BP 930 to 900) and Cal AD 1100 to 1140 (Cal BP 850 to 810)



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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-27.4:lab. mult=1)

Laboratory number: **Beta-222041**

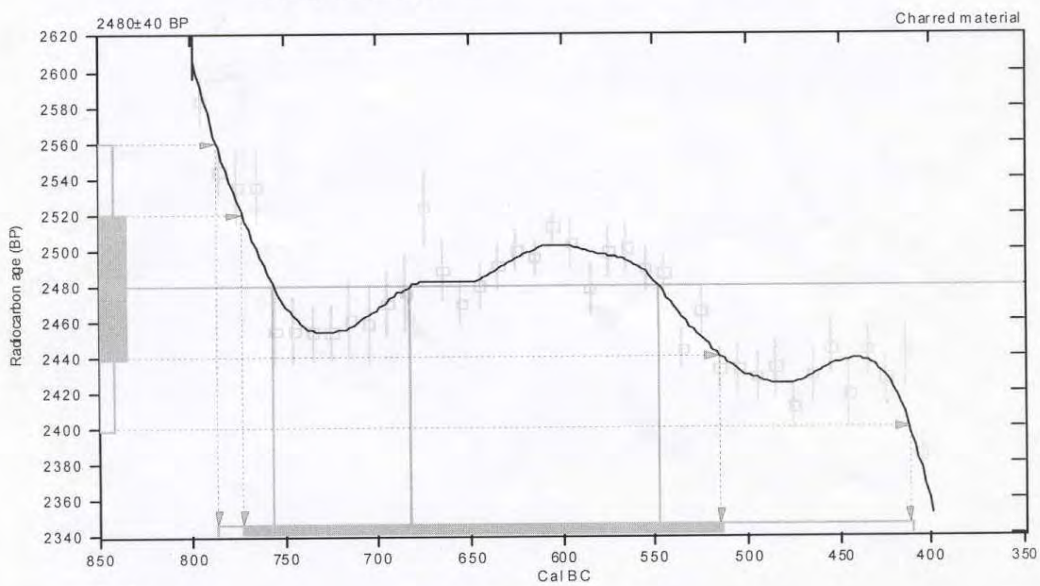
Conventional radiocarbon age: **2480±40 BP**

2 Sigma calibrated result: (95% probability) **Cal BC 790 to 410 (Cal BP 2740 to 2360)**

Intercept data

Intercepts of radiocarbon age with calibration curve: Cal BC 760 (Cal BP 2710) and Cal BC 680 (Cal BP 2630) and Cal BC 550 (Cal BP 2500)

1 Sigma calibrated result: (68% probability) Cal BC 770 to 520 (Cal BP 2720 to 2460)



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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26.2:lab. mult=1)

Laboratory number: **Beta-222042**

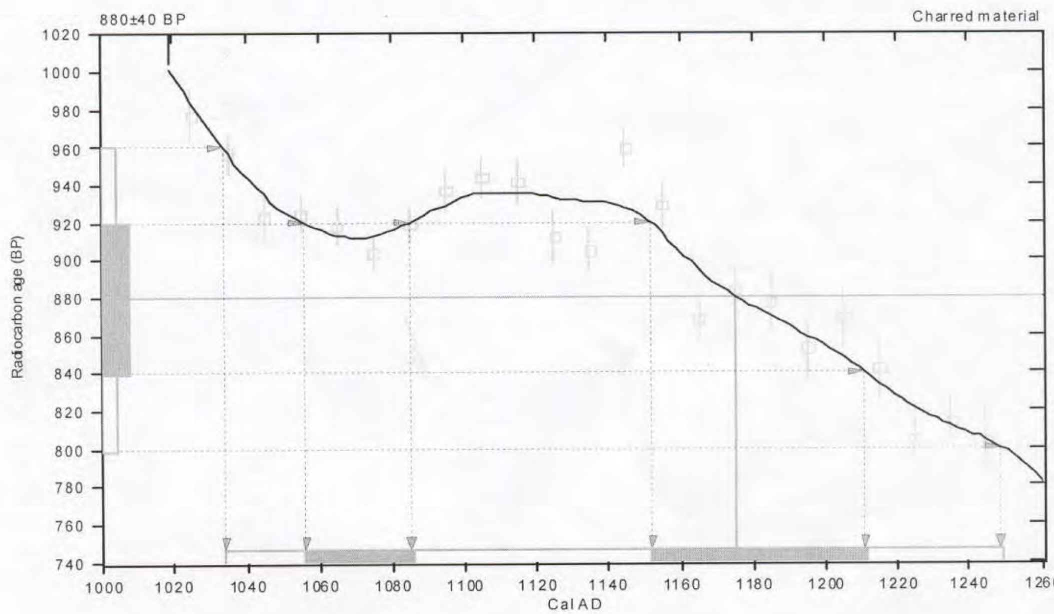
Conventional radiocarbon age: **880±40 BP**

2 Sigma calibrated result: (95% probability) **Cal AD 1030 to 1250 (Cal BP 920 to 700)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 1180 (Cal BP 780)

1 Sigma calibrated results: (68% probability) Cal AD 1060 to 1080 (Cal BP 890 to 860) and Cal AD 1150 to 1210 (Cal BP 800 to 740)



References:

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INTCAL98 Radiocarbon Age Calibration

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Appendix H
Landslide data

ArcGIS output for landslide totals across Upper Greybull by area.

*LS_TYPE	*Cnt_LS_TYP	Min_area	Max_area	Sum_area	*SD_area	*Var_area
Qal/mdf	1	124703.00	124703.00	124703.00	0.00	0.00
Qg/mdf	1	408630.00	408630.00	408630.00	0.00	0.00
Qg/mrg/mrf	1	1101010.00	1101010.00	1101010.00	0.00	0.00
Qg/rg	2	265930.00	380716.00	646646.00	81165.96	6587912898.00
Qlg	3	107392.00	455823.00	757392.00	181381.01	32899071217.00
Qt/f	2	125105.00	413780.00	538885.00	204124.05	41666627812.50
Qt/mdf	20	11150.80	590350.00	2621907.60	129349.05	16731175570.81
Qt/mdf/sw	2	179281.00	270371.00	449652.00	64410.36	4148694050.00
Qt/mrs	1	94815.40	94815.40	94815.40	0.00	0.00
Qt/mrs/mdf	1	886402.00	886402.00	886402.00	0.00	0.00
Qt/mtf/mdf	1	322075.00	322075.00	322075.00	0.00	0.00
Qt/rf/rs	15	39990.90	815791.00	3420238.90	209587.61	43926964459.27
Qt/rgi/rs	1	431569.00	431569.00	431569.00	0.00	0.00
Qt/rs	68	12139.20	676019.00	9111961.11	121860.62	14850011218.68
Qt/rs/rg	3	42881.70	554868.00	1060739.70	272965.97	74510420576.16
Qt/rs/rgi	1	217286.00	217286.00	217286.00	0.00	0.00
Qt/tf	3	47473.90	70949.90	186103.00	12715.31	161679060.22
a/f	1	176670.00	176670.00	176670.00	0.00	0.00
ac/mdf	1	14646.10	14646.10	14646.10	0.00	0.00
af/df	87	15205.70	351321.00	8179602.40	68414.64	4680562635.59
af/mdf	4	51598.60	242410.00	487717.50	86080.67	7409881334.88
av/df	3	24124.50	29753.40	80642.70	2816.25	7931239.24
blsl	8	22134.90	402581.00	942621.40	125609.50	15777746333.04
blsl/f	5	52145.70	281790.00	622054.30	93856.20	8808987108.20
blsl/mf	8	25345.50	535329.00	971962.91	170006.31	28902144430.82
blsl/ms/mf	1	286619.00	286619.00	286619.00	0.00	0.00
df	16	12037.30	1555890.00	3921184.80	377545.14	142540331076.81
df/Qal	1	20403.60	20403.60	20403.60	0.00	0.00
df/af	17	15154.40	166522.00	917401.90	42397.37	1797537138.46
df/av	2	45932.80	86110.00	132042.80	28409.57	807103668.53
df/sw	1	77106.10	77106.10	77106.10	0.00	0.00
f	69	4845.92	2231890.00	10805947.97	289551.36	83839991616.03
f/Qt	1	26308.90	26308.90	26308.90	0.00	0.00
f/blsl	2	22558.10	80210.30	102768.40	40766.26	1661887924.78
f?	4	142681.00	521445.00	1447541.00	158646.99	25168866690.92
fsel	1	24392.20	24392.20	24392.20	0.00	0.00
maf/df	1	482127.00	482127.00	482127.00	0.00	0.00
mbls/mrs/ms/mf	1	1362330.00	1362330.00	1362330.00	0.00	0.00
mblsl	3	12437.20	579675.00	690668.40	305682.43	93441750149.89
mblsl/Qlg	1	358312.00	358312.00	358312.00	0.00	0.00
mblsl/mrs	2	100083.00	820038.00	920121.00	509085.06	259167601012.50
mblsl/mrs/mf	10	81904.20	2256290.00	9374436.20	732942.55	537204784624.39
mblsl/mrs/ms/mf	1	681094.00	681094.00	681094.00	0.00	0.00

mblsl/ms	1	140191.00	140191.00	140191.00	0.00	0.00
mblsl/ms/mdlef	1	4996990.00	4996990.00	4996990.00	0.00	0.00
mblsl/ms/mf	9	176568.00	3275970.00	12370318.00	1089620.92	1187273744320.19
mblsl/sw	1	292062.00	292062.00	292062.00	0.00	0.00
mdf	24	8863.71	281385.00	2049680.61	76160.94	5800488719.60
mdf/Qal	7	36873.70	325471.00	887785.00	94623.12	8953535695.92
mdf/Qt	8	41098.10	426253.00	1246469.30	133799.49	17902302800.98
mdf/ac	8	10036.40	47062.30	212019.20	15797.93	249574592.47
mdf/ac/sw	1	252643.00	252643.00	252643.00	0.00	0.00
mdf/af	20	21999.20	261731.00	1742661.81	64145.98	4114707183.50
mdf/av	1	106848.00	106848.00	106848.00	0.00	0.00
mdf/mrs	1	60884.70	60884.70	60884.70	0.00	0.00
mdf/sw	10	23127.80	257010.00	1265956.00	80564.04	6490563917.43
mf	29	7077.35	737431.00	5208339.57	219541.18	48198331888.75
mf/colluvium	1	174676.00	174676.00	174676.00	0.00	0.00
mf/creep	1	96855.50	96855.50	96855.50	0.00	0.00
mf/f	1	194566.00	194566.00	194566.00	0.00	0.00
mf/mdf	1	56823.60	56823.60	56823.60	0.00	0.00
mf/mdf/Qal	1	143240.00	143240.00	143240.00	0.00	0.00
mf/mdf/ms	1	1495190.00	1495190.00	1495190.00	0.00	0.00
mf/solif	1	547644.00	547644.00	547644.00	0.00	0.00
mf/sw	1	79306.90	79306.90	79306.90	0.00	0.00
mrg/Qg	2	194532.00	292181.00	486713.00	69048.27	4767663600.50
mrg/Qlg	3	80596.90	813963.00	1019016.90	411332.81	169194678577.68
mrg/mdf/Qg	1	839543.00	839543.00	839543.00	0.00	0.00
mrs	1	48256.70	48256.70	48256.70	0.00	0.00
mrs/Qlg	1	207880.00	207880.00	207880.00	0.00	0.00
mrs/Qt	1	343302.00	343302.00	343302.00	0.00	0.00
mrs/f	1	202517.00	202517.00	202517.00	0.00	0.00
mrs/mblsl/mf	1	377446.00	377446.00	377446.00	0.00	0.00
mrs/mdf	8	18267.20	163559.00	607255.50	56511.67	3193568621.81
mrs/mdf/af	2	128553.00	339458.00	468011.00	149132.36	22240459512.50
mrs/mdf/sw	1	39254.90	39254.90	39254.90	0.00	0.00
mrs/mf	17	24266.20	2040330.00	8088597.60	581085.72	337660615018.88
mrs/mf/sw	1	490104.00	490104.00	490104.00	0.00	0.00
mrs/ms/mf	1	158908.00	158908.00	158908.00	0.00	0.00
mrs/rff/mf	1	1537040.00	1537040.00	1537040.00	0.00	0.00
ms	24	21212.10	647555.00	2774308.50	133133.60	17724555692.49
ms/blsl	1	428295.00	428295.00	428295.00	0.00	0.00
ms/f	76	23826.00	2199230.00	26790384.50	408876.87	167180297234.13
ms/f/rs	2	677961.00	1125530.00	1803491.00	316479.07	100159004880.50
ms/mblsl	1	45791.80	45791.80	45791.80	0.00	0.00
ms/mf	34	3640.33	7073340.00	35430447.13	1545308.38	2387977974928.27
ms/mf/blsl	5	355879.00	6871110.00	14968519.00	2995118.92	8970737349842.19
ms/mf/mdf/sw	1	277908.00	277908.00	277908.00	0.00	0.00
ms/mrs/mf	2	352722.00	775111.00	1127833.00	298674.13	89206233660.50
ms/rs	7	30517.40	1567830.00	4469683.40	514021.07	264217658925.45
ms/rs/f	1	926269.00	926269.00	926269.00	0.00	0.00
Mtf/mdf	1	23271.70	23271.70	23271.70	0.00	0.00

Mtf/rg	1	150667.00	150667.00	150667.00	0.00	0.00
older flow	1	1088840.00	1088840.00	1088840.00	0.00	0.00
older ms/mf	1	125176.00	125176.00	125176.00	0.00	0.00
older slide mass	2	773902.00	1001480.00	1775382.00	160921.95	25895873042.00
older slide mass?	1	416876.00	416876.00	416876.00	0.00	0.00
older slump?	1	110682.00	110682.00	110682.00	0.00	0.00
r/rs	2	51846.00	81781.50	133627.50	21167.60	448067080.13
Rf	1	53652.50	53652.50	53652.50	0.00	0.00
rf/rs	9	14369.30	362097.00	1225081.30	112326.10	12617152950.03
rf/rs/f	1	121619.00	121619.00	121619.00	0.00	0.00
rf/rs/tf	2	106641.00	543805.00	650446.00	309121.63	95556181448.00
Rg	10	23675.30	757053.00	2201366.30	220949.39	48818633134.25
rg/Qlg	1	376110.00	376110.00	376110.00	0.00	0.00
rg/Qt	1	317496.00	317496.00	317496.00	0.00	0.00
rg/Qt/rs	1	1004960.00	1004960.00	1004960.00	0.00	0.00
rg/blstrm/Qg	1	516833.00	516833.00	516833.00	0.00	0.00
rg/mdf	2	130029.00	450718.00	580747.00	226761.37	51420717360.50
rg/rs	7	67838.10	1090200.00	2491518.90	346173.21	119835890059.24
Rgi	18	10880.40	600735.00	2126860.10	139750.52	19530208699.74
rgi/Qt	1	48661.30	48661.30	48661.30	0.00	0.00
Rs	64	11233.60	411903.00	5127946.88	88355.15	7806632294.43
rs/Qt	25	22092.70	251639.00	1819772.10	54773.86	3000175272.11
rs/Qt/df	1	72234.30	72234.30	72234.30	0.00	0.00
rs/af	1	97869.30	97869.30	97869.30	0.00	0.00
rs/blsl/f	1	1072010.00	1072010.00	1072010.00	0.00	0.00
rs/df	11	36983.20	282495.00	1032523.29	71402.91	5098375651.63
rs/f	26	36277.80	637701.00	4788968.41	152232.44	23174714926.52
rs/f/Qt	1	53831.70	53831.70	53831.70	0.00	0.00
rs/f?	1	102473.00	102473.00	102473.00	0.00	0.00
rs/mdf	1	29825.90	29825.90	29825.90	0.00	0.00
rs/rf	1	178674.00	178674.00	178674.00	0.00	0.00
rs/rg	2	83591.60	166883.00	250474.60	58895.91	3468728526.84
rs/rgi	1	53928.70	53928.70	53928.70	0.00	0.00
rs?	1	58509.90	58509.90	58509.90	0.00	0.00
S	22	7964.47	156737.00	1206236.30	41996.17	1763678436.11
s/blsl	4	46465.90	139003.00	323771.90	41785.82	1746054608.37
s/df	2	40718.60	110468.00	151186.60	49320.27	2432489291.20
s/f	73	14707.10	1576290.00	10646748.41	197198.37	38887198274.56
s/mblsl/f	1	587410.00	587410.00	587410.00	0.00	0.00
s/rs	29	23923.60	690564.00	4263624.40	144292.68	20820378036.05
s/rs/f	2	356925.00	2110110.00	2467035.00	1239689.00	1536828822112.50
s/tf	1	221002.00	221002.00	221002.00	0.00	0.00
shallow flow	2	84385.40	113920.00	198305.40	20884.12	436146344.73
solif	13	22503.70	137512.00	998737.91	37225.81	1385760873.09
solif/Qt/tf	1	311190.00	311190.00	311190.00	0.00	0.00
solif/mf	5	23380.20	188684.00	584455.20	59338.77	3521089340.44
solif/mf/sw	1	247878.00	247878.00	247878.00	0.00	0.00
solif/sw	2	303695.00	454807.00	758502.00	106852.32	11417418272.00
solif/sw/mf	1	677200.00	677200.00	677200.00	0.00	0.00

solif/tf	1	86803.60	86803.60	86803.60	0.00	0.00
sw/mdf	2	31582.20	182999.00	214581.20	107067.85	11463523779.41
sw/ms/mf	1	311935.00	311935.00	311935.00	0.00	0.00
ta/rs	1	91875.20	91875.20	91875.20	0.00	0.00
Tf	10	18808.20	194044.00	872985.70	65390.94	4275975520.98
tf/Qt	2	36891.90	123284.00	160175.90	61088.44	3731797606.19
tf/Qt/solif	1	290491.00	290491.00	290491.00	0.00	0.00
tf/mdf/Qt	1	201113.00	201113.00	201113.00	0.00	0.00
tf/mf	1	46971.00	46971.00	46971.00	0.00	0.00
tf/mrs/Qt	1	671855.00	671855.00	671855.00	0.00	0.00
tf/rg	2	89197.80	115494.00	204691.80	18594.22	345745149.40
tf/rgi	1	103535.00	103535.00	103535.00	0.00	0.00
tf/rs	1	64184.60	64184.60	64184.60	0.00	0.00
tf/solif	1	263537.00	263537.00	263537.00	0.00	0.00

Key
*LS_TYPE: landslide type
*Cnt_LS_TYP: frequency of occurrence of specific landslide type
*SD_area: standard deviation of area covered by specific landslide type
*Var_area: variance of area

ArcGIS output for archaeological sites and landslide shared area.

*OBJECTID	LS_TYPE	Shape_Leng	Shape_Area	*FID_allsit	*FIELDSITE	*area_clip
837	mrs/mf	7343.05	2033438.08	145	WR007	1335.00
877	s/f	2495.59	336968.41	18	FF002	1895.00
905	older flow	4953.20	1085481.84	15	FF005	1750.00
905	older flow	4953.20	1085481.84	16	FF004	3040.00
905	older flow	4953.20	1085481.84	17	FF003	4439.00
905	older flow	4953.20	1085481.84	18	FF002	281.00
905	older flow	4953.20	1085481.84	19	FF001	30293.00
927	ms/f	4417.02	772794.57	44	EL002	4058.00
927	ms/f	4417.02	772794.57	45	EL001	7835.00
927	ms/f	4417.02	772794.57	46	EL006	2375.00
927	ms/f	4417.02	772794.57	47	EL003	8452.00
947	rs/af	1835.68	97598.54	43	GR033	278.00
951	rs/df	1850.57	88312.23	53	JC037	4119.00
970	s/f	2091.70	175358.84	38	VIC001	3719.00
970	s/f	2091.70	175358.84	39	VIC002	7966.00
979	af/df	4131.75	183578.66	40	WAR002	1305.00
979	af/df	4131.75	183578.66	41	WAR004	2795.00
979	af/df	4131.75	183578.66	42	WAR001	3335.00
979	af/df	4131.75	183578.66	43	GR033	145.00
1379	F	11321.80	2225170.23	89	GR027	1771.00
1384	F	1972.21	225269.75	140	JC026	328.00
1456	af/df	1961.98	129987.87	90	GR023	2894.00
1456	af/df	1961.98	129987.87	139	GR022	606.00
1505	af/df	2315.67	120090.11	134	GR031	11538.00
1505	af/df	2315.67	120090.11	135	GR030	1476.00
1539	s/f	621.48	25674.48	68	JC040	422.00
1550	Mf	3787.00	735266.90	67	JC036	2498.00
1551	mf	3522.15	506122.48	69	JC001	491.00
1576	s/f	1929.17	250147.96	13	JC045	2758.00
1576	s/f	1929.17	250147.96	60	JC041	2969.00
1606	rf/rs	3332.65	361065.99	51	GR017	3140.00
1611	ms/f	6163.23	2192846.57	5	JC065	3468.00
1611	ms/f	6163.23	2192846.57	6	JC064	15146.00
1611	ms/f	6163.23	2192846.57	9	JC052	104.00
1611	ms/f	6163.23	2192846.57	13	JC045	3757.00
1611	ms/f	6163.23	2192846.57	14	JC046	2896.00
1611	ms/f	6163.23	2192846.57	54	JC034	4634.00
1611	ms/f	6163.23	2192846.57	55	JC033	6105.00
1611	ms/f	6163.23	2192846.57	56	JC010	12150.00
1611	ms/f	6163.23	2192846.57	57	JC032	740.00
1611	ms/f	6163.23	2192846.57	61	JC008	23101.00
1611	ms/f	6163.23	2192846.57	62	JC002	68709.00
1611	ms/f	6163.23	2192846.57	63	JC014	22897.00

1611	ms/f	6163.23	2192846.57	64	JC016	3858.00
1611	ms/f	6163.23	2192846.57	65	JC035	3401.00
1611	ms/f	6163.23	2192846.57	66	JC006	3543.00
1611	ms/f	6163.23	2192846.57	6	JC064	1187.00
1611	ms/f	6163.23	2192846.57	55	JC033	1187.00
1640	ms/mf	4616.50	1316562.22	58	JC043	3595.00
1640	ms/mf	4616.50	1316562.22	59	JC044	666.00
1667	ms/f	6100.21	1826141.32	7	JC059	14012.00
1667	ms/f	6100.21	1826141.32	8	JC056	5983.00
1667	ms/f	6100.21	1826141.32	9	JC052	9837.00
1667	ms/f	6100.21	1826141.32	10	JC051	6505.00
1667	ms/f	6100.21	1826141.32	11	JC050	6275.00
1667	ms/f	6100.21	1826141.32	12	JC047	1126.00
1699	Qt/rf/rs	5304.78	268915.51	33	WAR006	90.00
1713	ms/f	2573.39	406860.88	137	PC003	2018.00
1718	s	1420.75	120896.07	31	WAR010	392.00
1765	df	28113.96	1551794.71	35	WAR008	17149.00
1778	s/f	3750.01	547947.34	3	PC013historic	862.00
1778	s/f	3750.01	547947.34	4	PC013	4551.00
1778	s/f	3750.01	547947.34	24	PC006	12932.00
1778	s/f	3750.01	547947.34	25	PC011	4218.00
1778	s/f	3750.01	547947.34	26	PC005	1388.00
1782	ms/mf	9616.28	2281986.95	3	PC013historic	403.00
1782	ms/mf	9616.28	2281986.95	4	PC013	225.00
1782	ms/mf	9616.28	2281986.95	26	PC005	1724.00
1782	ms/mf	9616.28	2281986.95	27	PC002	19361.00
1782	ms/mf	9616.28	2281986.95	28	PC004	1139.00
1843	s/rs	5170.60	688818.52	2	PT002	1368.00
1883	s/f	1599.22	120028.50	0	PT003	3154.00
15441	s/f	1739.36	120890.31	95	JC024	313.00
15441	s/f	1739.36	120890.31	96	JC017	1566.00
15446	s/f	2122.42	213395.82	97	JC023	1044.00
15446	s/f	2122.42	213395.82	98	JC018	3842.00
15446	s/f	2122.42	213395.82	99	JC019	15431.00
15446	s/f	2122.42	213395.82	100	JC020	2744.00
15446	s/f	2122.42	213395.82	101	JC021	7311.00
15504	rg/rs	6701.67	1086567.92	102	MC001	9204.00
15504	rg/rs	6701.67	1086567.92	103	MC002	2062.00
15504	rg/rs	6701.67	1086567.92	106	MC012	1343.00
15504	rg/rs	6701.67	1086567.92	108	MC011	157.00
15507	mdf/af	1535.67	104877.86	113	MC003	7106.00
15572	mdf/sw	2554.92	251691.39	120	HC001	6305.00
15610	af/df	2168.78	105443.57	115	DC001	2625.00
15610	af/df	2168.78	105443.57	116	DC002	3023.00
15613	af/mdf	2621.01	123916.73	116	DC002	1030.00
15615	af/mdf	4509.85	241594.34	117	DC003	1086.00
15617	mblsl/mrs/mf	5677.79	1810748.81	114	WR002	1965.00
15724	mrs/mf	7748.47	1458986.48	119	WR006	1422.00
16043	rgi	4655.58	598629.43	122	DM010	526.00

16043	rgi	4655.58	598629.43	123	DM001	15005.00
16043	rgi	4655.58	598629.43	124	DM005	427.00
16043	rgi	4655.58	598629.43	125	DM004	809.00
16043	rgi	4655.58	598629.43	126	DM014	575.00
16043	rgi	4655.58	598629.43	127	DM007	164.00
16043	rgi	4655.58	598629.43	128	DM006	4827.00
16043	rgi	4655.58	598629.43	129	DM009	1120.00

Key
*OBJECTID: ID number for specific landslide formation
*FID_allsit: ID number for archaeological site
*FIELDSITE: Field ID name for archaeological site
*area_clip: area shared by landslide formation and archaeological site based on "Clip" function results

ArcGIS output for projectile points associated with landslide formations.

SI_	TEMPSITE	CL	EL	POR	MAT	TIME	OBJECTID	LS_TYPE
48PA2726	DM006	CS	PP	ME	QT	UA	16043	rgi
48PA2727	DM007	CS	PP	PSH	CH	LA	16043	rgi
48PA2721	DM001	CS	PP	PSH	CH	EA	16043	rgi
48PA2770	HC001	CS	PP	CO	DMC	UA	15572	mdf/sw
48PA2719	DC002	CS	PP	PSH	CH	LA	15610	af/df
48PA2719	DC002	CS	PP	CO	CH	LA	15610	af/df
48PA2783	JC021	CS	PP	PSH	QT	LA	15446	s/f
48PA2782	JC020	CS	PP	PSH	CH	LA	15446	s/f
48PA2781	JC019	CS	PP	CO	PWD	LA	15446	s/f
48PA2780	JC018	CS	PP	PSH	IR	UA	15446	s/f
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48PA2815	PC006	CS	PP	CO	QT	LP	1778	s/f
48PA2815	PC006	CS	PP	PSH	SLS	UA	1778	s/f

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